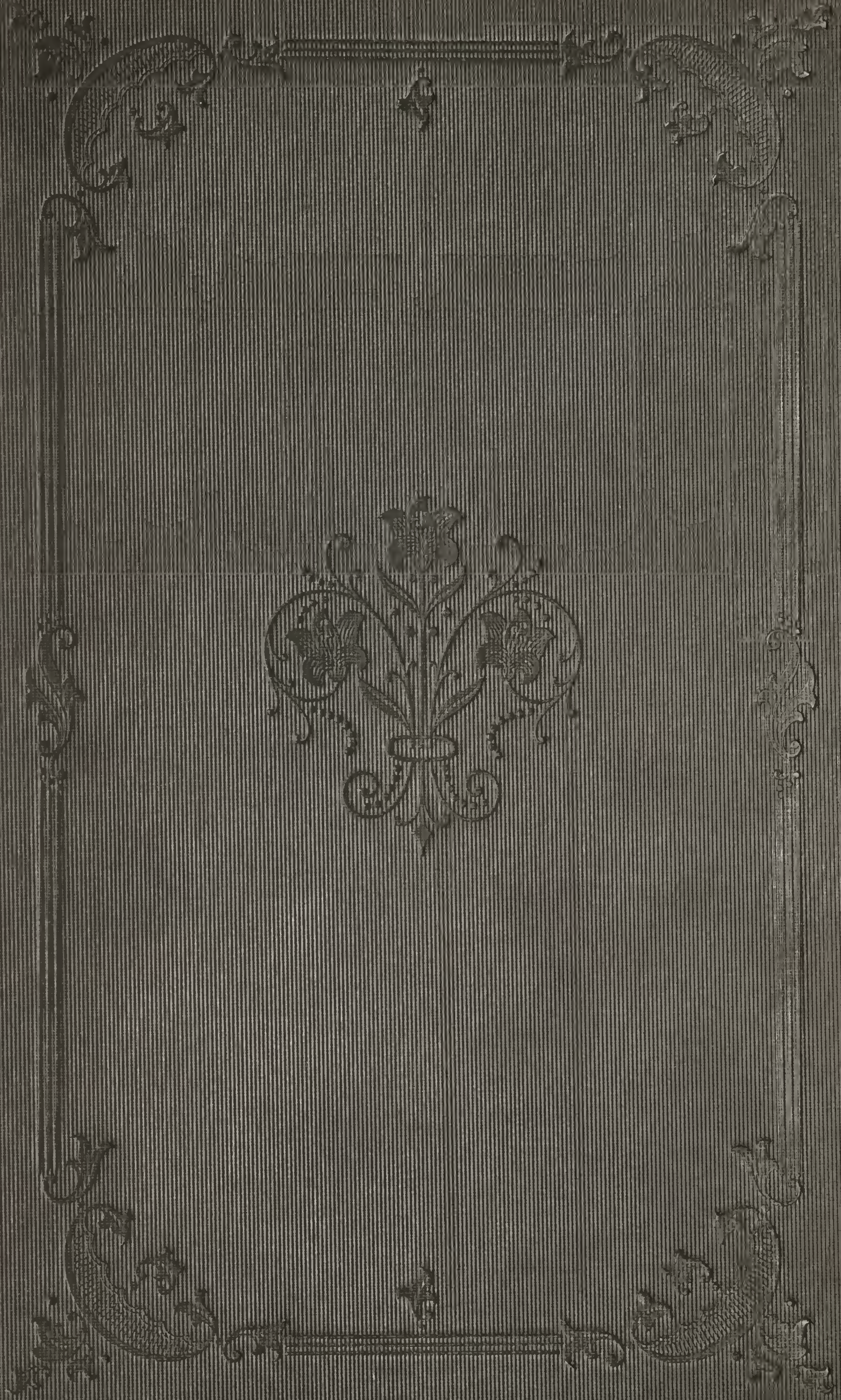


THE FOUNDATION LIBRARY
FOR YOUNG PEOPLE

COPYRIGHT [illegible] BY THE EDUCATIONAL SOCIETY

WONDERFUL DISCOVERIES AND INVENTIONS.

"To the inquiring youth it is desirable that he should be enabled to satisfy his wish to know by what means such wonders as Steam Navigation, Locomotion on Railways, the Electric Telegraph, and Photography have been gradually developed; and in becoming acquainted with the successive steps by which they have advanced toward their present perfection, he will at the same time learn a useful lesson of perseverance under difficulties, and will have his mind impressed with many valuable scientific truths. The knowledge to be gained is eminently practical, and of a kind which those engaged in any of the pursuits of life can scarcely fail to require."

—*Frederick C. Bakewell in Great Facts.*

"Scientific discovery goes hand in hand with invention, and they mutually assist each other's progress. Every discovery in science may be applicable to some new purpose, or give greater efficiency to what is old. These new and improved instruments and processes provide science with the means of extending its researches into other fields of discovery; and thus, as every truth revealed supplies inventive genius with fresh matter to mould into new forms, those creations become in their turn agents in promoting further discoveries."—*Otis T. Mason, Proceedings and Addresses United States Patent Office Report.*

COPYRIGHT 1911 BY THE EDUCATIONAL SOCIETY

THE
FOUNDATION LIBRARY
FOR YOUNG PEOPLE

A COMPREHENSIVE AND SYSTEMATIC PRESENTATION OF PRACTICAL AND ESSENTIAL KNOWLEDGE, WRITTEN IN AN INTERESTING AND INSTRUCTIVE WAY FOR CHILDREN AND YOUTH; DESIGNED TO INFORM THE MIND, STIMULATE AMBITION, ELEVATE IDEALS, AND CREATE RIGHT AND HEALTHY VIEWS OF LIFE AND CONDUCT. ALSO INTENDED TO AID PARENTS, TEACHERS, AND ALL OTHERS INTERESTED IN THE CULTURE AND TRAINING OF THE YOUNG

VOL
X

COMPLETE
IN ELEVEN VOLUMES
ILLUSTRATED

THE EDUCATIONAL SOCIETY
CHICAGO NEW YORK TORONTO

AC5
.F7

COPYRIGHT 1911
BY
THE EDUCATIONAL SOCIETY

© Cl.A297684

mar 27 '11

Contributors to Volume X.

FREDERICK CONVERSE BEACH, Ph.B.
Editor-in-Chief.
Editor, The Scientific American.

ARTHUR H. ELLIOTT, Ph.D.
Engineer-Chemist; Lecturer in Columbia University on Fuels, Etc.; Author of Qualitative Analysis.

A. F. MACKAY
Typographic Department, Lanston Monotype Machine Company, Philadelphia, Pa.

GROVER CLEVELAND LOENING, B.Sc., A.M.
Author of Monoplanes and Biplanes.

J. HORACE McFARLAND
Master Printer, Editor, Author, and Lecturer.

A. D. RISTEEN, Ph.D.
Of the Hartford Steam Boiler Inspection and Insurance Company.

ANTHONY FIALA
Explorer; Author of Fighting the Polar Ice.

ALBERT SONNICHSEN
Journalist and Author.

C. H. CLAUDY
Special Correspondent; Writer of Illustrated Articles.

HEREWARD CARRINGTON
Author The Coming Science, etc., and contributor to Journals on Scientific and Psychic Subjects.

Contents of Volume X.

PAGE
INTRODUCTION xxix

PART I.—THE CLOTHING OF MAN.

CHAPTER I. THE STORY OF WOOL.

An Humble Servant 1
A Civilizer—Wild but not Woolly 1
After Wool, Weaving 3
American Weaving Started by a Minister 3
"All Wool" and "Part Cotton" 4

CHAPTER II. SILK: ITS HISTORY, MANUFACTURE AND USES.

The Little Silk Worm and His House 5
Where Silk First Came From 6
How Silk Drinks Water, and what Comes of It 7
What the British Thought about Silk in America 8
How the Raw Silk is Worked Up 9
Where Silk gets Rheumatism 11
How Silk Frets, and the Result 12
Something that Looks Like Silk, but Isn't 12
How Silk gets Its Beautiful Color 12
Things that are Made of Silk 14

CHAPTER III. THE GREAT LINEN INDUSTRY.

A Trade that Goes Back Thousands of Years 15
Where Mists are a Good Thing 15
A New Kind of Language 15
A Machine that can do Everything but Talk 16
Another Intelligent Machine 17
Some Odd Facts about Linen 17
Names from Across the Sea 19
When Linen is Not Linen at All 19
Cloth that Holds Its Own 20
How to have Designs upon Linen 20

CHAPTER IV. LACE-MAKING.

A Lovely Art 21
Many Varieties of Lace 22

PAGE
Something Else than Hands that can Make Lace... 23
A Fine Deed of English Noblewomen 23
The Beautiful Belgian Laces 24
Laces of Other Races 25
Some Famous Old Laces 26
Lace-Making in America 26
Nothing Like Hand-Work after All.............. 27

CHAPTER V. VELVET.
A Soft Art Learned by Men of War............. 28
How Velvet Ministered to Religion 28
Velvet and Vanity 29
France the Modern Home of Fine Velvet.......... 29
Velvet and the Coronation 29
A Bit of German History 30
How Velvet gets its Fur 30
A Group of Interesting Velvet-Facts 31
Velvet, Velvet Everywhere 32
Plush and Other Near Velvets 32
The Fineness of Fine Velvet 33

CHAPTER VI. THE COTTON INDUSTRY.
How the Vegetable Lamb came to Europe.......... 33
A Romance and a Tragedy 34
How a College Student Created an Industrial Revolution 37
Negro Slavery, and a Machine that would have Abolished it Without War 40
A Machine that Forecasts a still more Tremendous Revolution 42

CHAPTER VII. SPINNING AND WEAVING MACHINERY.
An Ancient and Honorable Craft 45
A Machine with a Woman's Name 47
A Machine Named after an Animal 47
Many Machines of Many Names 47

CHAPTER VIII. THREAD MANUFACTURE.
From Egyptian Distaff to Indian Wheel.......... 49
From One Wheel to Many Wheels 49
Spinning Yarns and Thread 50
Giving a Twist to It 50
The String Tribe 52
An Interesting Thread Incident 52

PAGE

CHAPTER IX. THE SEWING MACHINE.

Men Trying to Make Woman's Work Easier........ 52
The First Man who Began to Succeed........... 53
The Man who First Succeeded 53
Others who Succeeded, Too 53
Another Case of where America Got in First........ 54
A Great Combination 54
The Wonders of the Modern Machine 55
The Baby of Them All 56

CHAPTER X. THE HISTORY OF A HAT.

The Roman and the Little Round Hat............ 56
A Good Machine with a Wicked Name............ 57
Following a Hat Through the Making............ 57
A Civil War Incident 59
The Hat in History 59
Evolution of the Cool Straw Hat............... 61
The Panama Hat which is not a "Panama" at All... 63

CHAPTER XI. THE LEATHER INDUSTRY.

A Better use to Make of Skins than Eating Them... 64
A Process Scientific, but Older than Science....... 65
Another Good Act of the Stern Old Pilgrim Fathers 65
What Happens when Chemist and Tanner Join Forces 67
Many Leathers of Many Names................ 69
Old Ways of an Old Industry 69
Steel Slaves of the Shoe Trade 71
New England's Chief Industry 74

CHAPTER XII. RUBBER AND RUBBER FABRICS.

An Aristocratic Relative for a Dockyard Weed..... 75
How Rubber is Harvested 75
Crude Rubber gets Different Treatment in Different Countries 76
Other Words that mean "Rubber"................ 76
Out of Bitter Poverty Achievements of Untold Value 76
The Secret is Discovered and with it Success....... 77
Other Ways now of Sulphurizing 78
The First Shoes that Made a Trip to Boston....... 78
From Overshoe to "Congress" Shoe 79
Keeping Dry in the Wet 80
Old Enemies—Oil and Water 80
But Time Fails for Telling All 81

PAGE

PART II.—PROVIDING FOOD FOR MAN.

CHAPTER XIII. THE WONDERS OF MODERN AGRICULTURE.

The Idea of a Thoughtful Savage 83
The Idea Overturned more than the Soil.......... 84
How the Idea Changed Civilization 85
Evolution of the Idea 86
The Idea Comes to America 87
What America did to the Idea 88
The Idea Goes "Out West" and Grows with the Country 88
The Inseparable Companion of the Plow 89
Something for the Farmer's Wife and Children to Do 90
Even the Farmers Themselves Fell Behind......... 90
Casting Seeds with Iron Hands 91
Many Inventors—Two Types of Machines 92
Insurance Against Starvation 93
Another Idea we may Thank Barbarians for........ 94
How the Idea Lived and Came to England......... 94
On this Side the Sea—and Something Happens..... 96
Another Machine that went West 97
How the Reaper Helped us to Win the War........ 97
The Reaper's Lineal Descendant—The Harvester... 98
How the Reaper Builds Our Cities 98
A Contrivance of Two Illinois Brothers 100
The Greatest Work of the Harvester 103
Getting it Ready to be a Food.................. 103
What Every Farmer could Make for Himself....... 104
Ears, not Stalks 104
Stalks and Ears Both 105
Getting the Corn and Cob Apart................ 105
A Brother to the Reaper 106
Children of the Reaper's Brother 106

CHAPTER XIV. SPECIAL MACHINERY ON AND OFF THE FARM.

Driving the Horse off the Farm................. 108
What the Automobile Brought to the Farmer...... 109
Gasoline can Turn Its Hand to Many Uses........ 109
Finding a Better Use for Alcohol than Drinking It.. 109
What Happens to Grain when it Leaves the Farm.. 110
A Picturesque Process Praised by Poets.......... 110
A Process not Political but Practical 111

PAGE
The Wheat Grain as Berries 112
Rollers that do not Roll 112
The Gravity Road that Grain Goes Over 113
Things to Eat are Our Greatest Industries........ 115

CHAPTER XV. MODERN DAIRY METHODS.

The First and Best of Food 115
What the Pretty Dairy Maid From a Far-off Time Wouldn't Find 116
What the Same Dairy Maid Would Find........... 117
A Machine that Ousts Both Calf and Maid........ 117
Disentangling Milk from Cream 118
A Churn Without a Mistress 121
The Mythical Dairy Maid Again 124

CHAPTER XVI. THE MEAT INDUSTRY.

A Trail of Blood Through History 124
Humane Killing Versus Butchery 125
A Swift Trolley Ride to the Chill Room........... 126
A Porker on His Way to Pork 128
Animal Death no Longer a Menace to Human Life.. 129
The New Era of Canning and what it Means to Us.. 131
How Refrigeration, that Enriches our Menu, is Accomplished 133
It is Science that has Made all this Possible........ 135

CHAPTER XVII. POULTRY INCUBATORS.

Little Fellows not Motherless, but Unmothered..... 136
What is a Coop Without a Mother?.............. 137
Science Giving Pointers to the Mother Hen........ 137
A Hen's Nest that is Not a Hen's Nest........... 138
What Should be Done at the Hen's Lunch Hour.... 138
A Substitute for Dewy Feathers................ 139
A Lamp in Lieu of Warmth of Wing............. 139
Wonderful Growth of the Babies 142
The Supreme Mystery of Life 143
Still the Little Orphans Need Care............... 143
Cold Storage Eggs better than They Sound........ 144

CHAPTER XVIII. THE CANNING INDUSTRY.

Eating is an Old Habit—But Not Canning........ 146
The Greedy Appetites of Bad Germs............. 146
Work that Tries the Temper 147
The Home Kitchen and the Canning Factory...... 148

PAGE
A Visit to a Canning Factory 148
A Factory that Makes Cans as Well as Fills Them... 150
Canning on a Large Scale 150
All the World a-Canning 151
Pungent Pickles and Preserves 152
A Pretty Story with a Peppery Tang 153
The Old Family Recipe Book 154
The Jolly Good Jams of England 154
Jelly-Making in Factories, and "Making Jell" at Home 155

CHAPTER XIX. THE FRUIT INDUSTRY.

The Luscious Fruits of Today 156
A Discomfort Age of the Race 156
Modern Fruit Marvels 157
The Orchard at the Door 157
Classification of Fruits 158
The Wholesome Home-Loving Apple 158
The Juicy Pear, Cousin to the Apple 159
The Soft-Cheeked Peach 159
Plums—and Prunes 160
A Golden Tale of Magic 160
A Rich Fruit from Poor Land 162
The Large Subject of Small Fruits 163
Figs, Dates, and Bananas are getting Naturalization Papers 164
The "Rich, Brown Nut" 165
The Era of New and Improved Fruit 165
"Pleasant to the Sight and Good for Food" 166

CHAPTER XX. SUGAR AND CANDY MAKING.

Our Grandmother's Old China Sugar Bowl 167
From Sap to Sugaring-off 167
Other Sugar in the North 169
Half-Way Between North and South 169
South now— but, First, Molasses 170
The Whole Semi-Tropical World a Vast Sugar Factory 170
The Great Sugar Refineries of Today 171
A Black Hen, White Sugar, and an Observant Man 172
Sugar of Course Suggests Candy 172
Keeping it Just About Hot Enough 173
From Pearl to Caramel 174

PAGE
Other Helps to Candy Culture 174
Making Candies Look Good 174
The Horn of Sugar Plums 174
Looking into the World's Candy Window.......... 175
Candy as Decorations 177
Candy and Laughter go Together 178
When Candy-Making Came to New York.......... 178
The Deft French and Their Dainty Candies........ 178

CHAPTER XXI. TEA.
When "Tea" was "Tay" 179
The National Drink of the English 179
Teas and Tea Drinking of Various Nations 180
But Chinese and Tea are the True Partners........ 180
Tea Picking 181
Tea Drying 182
Tea Culture Outside of China 182
The Tea-Caravan and the Steamship 183
A Curious Fact 183
"Making Tea" an Art.......................... 184
The Two Chemicals in Tea 184
The Question of Milk and Sugar in Tea.......... 184
Tea as Money 185
Going Back to China, where we Started from...... 185

CHAPTER XXII. SALT.
A Universal Craving 186
Salt in History 187
Sources of Salt 188
Natural Brine 188
Down in a Salt Mine 188
The "Wich" in Names of English Towns.......... 190
Saturation of Salt 190
The Evaporation Process 191
Kinds of Salt 191

PART III.—DISCOVERIES AND INVENTIONS CONTRIBUTING TO THE ADVANCEMENT OF KNOWLEDGE.

CHAPTER XXIII. THE GREAT PAPER MAKING INDUSTRY.
One of the Essentials to Progress 192
What the Dictionary says Paper Is.............. 192
Long Before Paper—What? 193

PAGE
What the Wonderful Chinese Invented........... 193
The Principle that Underlies Paper-Making 193
Hand Work of Long Ago 194
The Great Machines of the Present............. 194
The Raw Materials for Paper-Making........... 195
Where Rags have a Real Use in the World......... 195
Wood Pulp and Its Preparation 196
How Paper is Made from Pulp—Rag or Wood...... 197
Book Paper 198
For the Daily Newspaper 199
Writing Paper 199
How Paper Gets Its Colors 199
Ready for the Printer 200

CHAPTER XXIV. TYPESETTING AND CASTING MACHINES.
A New and Wonderful Machine 200
A Milestone in the History of Printing.......... 201
What Joseph Thorne, an American, Did.......... 202
The Linotype 202
The Operation of the Linotype 204
The "Monotype" Machine 206
Features of the Monotype 206
A Future Combination 209

CHAPTER XXV. PRINTING, ONE OF THE GREATEST INVENTIONS.
The Conveyance of Thought 210
An Art a Thousand Years Old................. 211
Printing in Early Days 211
Typographic Printing 212
Lithographic Printing 213
Letter Design in Movable Type 213
Type has "Faces" 214
Sizes and Names of Type 215
The Font, or Composing Case 216
The Standard Line 216
What Type is Made of 216
The Fascinating Art of Typesetting 217
The Careful Proofreader 217
The Locking-up Process 218
Electrotyping 218
Stereotyping for the Rotary Press 220
Education in the Art of Printing 221

PAGE
The Early, Awkward Printing Presses 221
Two Forms of Printing Machines 222
The Old "Platen" Press 222
The Wonderful Modern Rotary Press 224
Specialized Printing Presses 226

CHAPTER XXVI. THE STORY OF THE PEN.

The Quill Pen and the Schoolmaster 227
When the Schoolmaster Got Tired............... 227
From a Soft to a Hard Pen..................... 228
How Steel Pens are Made 228
From Steel to Gold 229
Why the Tip is Slitted 229
The Sylographic and Fountain Pen 230

CHAPTER XXVII. THE LABOR-SAVING TYPEWRITER.

An Art that Stands Midway 230
France, England and America take a Hand in Invention 231
A Pretty Race between the United States and England 232
Different Forms of Typewriters 233
Making the Typewriter Perfect 234
A Blessing to the Blind 235
Typewriting as Compared with Longhand......... 236
America's Contribution to the Spread of Knowledge 236

CHAPTER XXVIII. THE MICROSCOPE.

A Doorway to a New World 236
The Discovery of the Microscope 237
Two Kinds of Microscopes 237
How the Microscopes Saved Industries and Lives... 237
The Amateur Microscope in the Home............ 238

CHAPTER XXIX. THE TELESCOPE.

The Lens and the Weathervane 238
The First Reflecting Telescope 239
Great Telescopes of the World 240
Famous Telescopes in the United States........ 240

CHAPTER XXX. PHOTOGRAPHY.

A Black Box with a Needle Hole in It 241
Chemistry Comes to the Aid of the Camera 242
Other Steps toward the Finished Picture.......... 243

PAGE
The Dark Room and the Negative 243
Gun Cotton and Its Aid in Picture-Making 244
Dry-Plate Photography 245

CHAPTER XXXI. THE THERMOMETER.
What the Thermometer is not 247
What the Thermometer is 247
How Thermometers are Made 248
The Three Standard Grades of Thermometers 248
Different Kinds of Thermometers 249
Looking at the Thermometer 249

CHAPTER XXXII. THE BAROMETER.
Measuring the Weight of the Air 249
How the Barometer Plays See-Saw with the Air 250
A Tall Barometer 251
Aneroid Barometers 251

CHAPTER XXXIII. MEDICAL DISCOVERIES AND INVENTIONS.
Inventions that Aid the Senses 251
An Electric Light Inside the Body 252
How One Man Looked into Another Man 254
A Button Like an Oyster Shell 254
How the Lungs and Heart put Themselves on Record 256
Measuring the Tired Feeling 256
A Threefold Diagnosis 257
Getting a Trial Balance of the Body 258
The Microscope in Medicine 259
How to Tell when One is Afraid 259
Instruments to Help Us to See and Hear 259
The X-Ray and Its Promise 261
Meaning of the Name 261
Source of the X-Rays 262
Photographic and Fluorescent Effects 262
Shadow Pictures 262
Effects of X-Rays upon the Human Body 263
Physical Nature of X-Rays 263

PART IV.—DISCOVERIES AND INVENTIONS FOR EXTENDING MAN'S EFFICIENCY AND POWER.

CHAPTER XXXIV. IRON, A MOST USEFUL METAL.
Things that are Taken as a Matter of Course 265
Iron, Iron, Everywhere 265

PAGE
The Awful Cost of Iron 266
A Sidewalk around the World 267
Transportation—The Shovels and the Cars........ 268
Ingenious Dumping at the Docks 269
Reloading on Steamers 270
How "Pig Iron" Got Out of the Ore............. 270
From Pig Iron to Cast Iron 271
From Cast Iron to Other Kinds................. 271
The "Iron City" 272
The "Metal of Progress" 273

CHAPTER XXXV. THE WONDERS OF STEEL.

The Era of Steel 273
An Enemy—But Mostly a Friend 275
A Process that Created a Household Word 275
How Steel Used to be Made 274
A Wonderful Art and a Beautiful Sight.......... 276
The Steel Cities of the United States........... 278
Steel in Other Countries 279
The Great Krupp Works 279
Where Temper is a Virtue 277
What Wonders Steel has Wrought............... 277
Arts of Peace as Well as War.................. 280
Consideration and Coöperation 281

CHAPTER XXXVI. STEAM BOILERS.

Strength of Boilers 282
Accessories 283
Safety-Valve 283
Scale 284
Boiler Explosions 284
The Sultana Explosion 285

CHAPTER XXXVII. STEAM TURBINES.

How a Turbine Differs from an Engine.......... 285
Reaction Turbines 286
The Impulse Turbine 287
The Combination Turbines 288
The Turbine on Steam Vessels 288

CHAPTER XXXVIII. GAS ENGINES.

Power by Explosion 289
How It Operates 290
What Occurs in the Cylinder 291

PAGE
The Dark Room and the Negative 243
Gun Cotton and Its Aid in Picture-Making 244
Dry-Plate Photography 245

CHAPTER XXXI. THE THERMOMETER.

What the Thermometer is not 247
What the Thermometer is 247
How Thermometers are Made 248
The Three Standard Grades of Thermometers 248
Different Kinds of Thermometers 249
Looking at the Thermometer 249

CHAPTER XXXII. THE BAROMETER.

Measuring the Weight of the Air 249
How the Barometer Plays See-Saw with the Air 250
A Tall Barometer 251
Aneroid Barometers 251

CHAPTER XXXIII. MEDICAL DISCOVERIES AND INVENTIONS.

Inventions that Aid the Senses 251
An Electric Light Inside the Body 252
How One Man Looked into Another Man 254
A Button Like an Oyster Shell 254
How the Lungs and Heart put Themselves on Record 256
Measuring the Tired Feeling 256
A Threefold Diagnosis 257
Getting a Trial Balance of the Body 258
The Microscope in Medicine 259
How to Tell when One is Afraid 259
Instruments to Help Us to See and Hear 259
The X-Ray and Its Promise 261
Meaning of the Name 261
Source of the X-Rays 262
Photographic and Fluorescent Effects 262
Shadow Pictures 262
Effects of X-Rays upon the Human Body 263
Physical Nature of X-Rays 263

PART IV.—DISCOVERIES AND INVENTIONS FOR EXTENDING MAN'S EFFICIENCY AND POWER.

CHAPTER XXXIV. IRON, A MOST USEFUL METAL.

Things that are Taken as a Matter of Course 265
Iron, Iron, Everywhere 265

PAGE
The Awful Cost of Iron 266
A Sidewalk around the World 267
Transportation—The Shovels and the Cars........ 268
Ingenious Dumping at the Docks 269
Reloading on Steamers 270
How "Pig Iron" Got Out of the Ore............. 270
From Pig Iron to Cast Iron 271
From Cast Iron to Other Kinds................. 271
The "Iron City" 272
The "Metal of Progress" 273

CHAPTER XXXV. THE WONDERS OF STEEL.

The Era of Steel 273
An Enemy—But Mostly a Friend 275
A Process that Created a Household Word 275
How Steel Used to be Made 274
A Wonderful Art and a Beautiful Sight........... 276
The Steel Cities of the United States............ 278
Steel in Other Countries 279
The Great Krupp Works 279
Where Temper is a Virtue 277
What Wonders Steel has Wrought............... 277
Arts of Peace as Well as War.................. 280
Consideration and Coöperation 281

CHAPTER XXXVI. STEAM BOILERS.

Strength of Boilers 282
Accessories 283
Safety-Valve 283
Scale 284
Boiler Explosions 284
The Sultana Explosion 285

CHAPTER XXXVII. STEAM TURBINES.

How a Turbine Differs from an Engine........... 285
Reaction Turbines 286
The Impulse Turbine 287
The Combination Turbines 288
The Turbine on Steam Vessels 288

CHAPTER XXXVIII. GAS ENGINES.

Power by Explosion 289
How It Operates 290
What Occurs in the Cylinder 291

PAGE
Relative Merits of the Engines 292
About Carbureters 294
About the Jump-Spark 295
"Throttling Governors" 296
The Problem of Starting 296

CHAPTER XXXIX. GAS PRODUCERS.
Need of Cheap Fuel Gas 297
How Coal Burns 297
Two Kinds of Oxides 298
Formation of the Dioxide 298
Formation of the Monoxide 299
Making the Monoxide from the Dioxide 299
Air Gas 300
Water Gas 301
Ordinary Producer Gas 301
The Continuous Process 302
Nature of the Coal that is Used.................. 303
"Scrubbing" the Gas 303
Pressure Producers 304
Suction Producers 304
Combination Producers 305

CHAPTER XL. THE DIESEL INTERNAL COMBUSTION ENGINE.
An Engine with New Devices 306
The Cycle of the Engine 306
A Distinctive Feature 307
A Motor of High Efficiency 307

CHAPTER XLI. THE STORY OF ELECTRICITY AND MAGNETISM.
Discovery of Electricity 308
Two Kinds of Electricity 308
Conductors and Non-Conductors 309
Static Form of Electricity 309
Discovery of the Voltaic Battery 310
Comparison with a Force Pump or a Water Pipe.... 310
Electric Pressure and Resistance 311
Units in which Electricity is Measured........... 311
Ohm's Law 312
Heating Effects 312
Mechanical and Magnetic Effects of Currents....... 312
Electric Induction 313
Nature of Electricity 314

PAGE

Magnetism—Magnets and Their Poles 314
Tendency to Point North and South 315
The Compass 315
Variation of the Compass 316
The Lodestone 316

CHAPTER XLII. CHANGE OF ELECTRICAL PRESSURE.

The Induction Coil 317
Transformers 318
Motor Generators 319

CHAPTER XLIII. MEASURING ELECTRICITY.

The Galvanometer 320
Measurement by Chemical Means 321
Ammeters and Voltmeters 321
Measuring Electrical Resistance 321
How Electricity is Produced 322
The Voltaic or Galvanic Battery 323
Polarization 324
The Daniell Battery 324
Gravity Battery 325
Bichromate Batteries 326
Sal Ammoniac Batteries 326
Dry Batteries 327
The Dynamo 327
Direct and Alternating Currents 328
Direct-Connected Machines 329
Electricity Direct from Coal 329
Thermo-Electricity 330

CHAPTER XLIV. THE TRANSMISSION OF POWER BY ELECTRICITY.

Individual Motors in Factories 331
Reasons for Transmitting Power 331
Importance of the Line Wires 332
Loss of Heat from the Line Wires 333
Choosing the Size of the Line Wires 333

CHAPTER XLV. CHEMICAL APPLICATIONS OF ELECTRICITY ELECTROLYSIS.

Davy's Experiments 334
Description of the Apparatus 334
Electrolytes and Non-electrolytes 335
Action is Confined to the Electrodes 335

PAGE
Primary and Secondary Products 335
Electroplating 336
Purification of Copper 336
Manufacture of Sodium, Magnesium and Aluminum 337
Manufacture of Chemical Compounds 337

CHAPTER XLVI. THE ELECTRIC FURNACE.

Principle of the Furnace 338
Household Heaters 338
The True Electric Furnace 338
Temperature of the Electric Furnace 339
Chemical Uses 339
Manufacture of Gems 340

CHAPTER XLVII. THE ELECTRIC MOTOR.

Early Motors 340
Dynamos and Motors Compared 341
Kinds of Motors 341
Series and Shunt Motors 342
Alternating Current Motors 343
Polyphase Motors 344
Induction Motors 345

CHAPTER XLVIII. THE STORAGE BATTERY.

It does not Store Electricity 346
Efficiency 346
Uses of the Storage Battery 346
The Lead Cell 347
The Two Main Types 347
What Happens in Charging the Battery 348
Discharging the Battery 349
Care in the Use of the Storage Battery 349
The Edison Battery 349

PART V.—MEANS OF TRANSPORTATION AND COMMUNICATION.

CHAPTER XLIX. THE MAIL COACH.

The Story of Traveling in Early Days 351
The Prairie Schooner of the Early Settlers 352
Interesting Rules of Stage Coach Days 353
The Stage Coach was Picturesque 354

CHAPTER L. THE STEAM ENGINE AND THE LOCOMOTIVE.

How the Steam Engine Works 356
The Principle of Expansion 356

PAGE
The Lazy but Resourceful Valve-Boy 356
The Slide Valve 357
Corliss Engines 357
Steadying Action of the Flywheel 358
Flywheel Explosions 358
The Governor 359
The "Safety Stop" 360
Condensing Engines 360
Compound, Triple, and Quadruple Engines........ 360
Power from a Pound of Coal...................... 361
Rotary Engines 361
Is Any Other Liquid Better than Water........... 362
The Locomotive as a Steam Automobile............ 363
Freight and Passenger Locomotive 363
Taking Water While Running 364
Qualifications of an Engineer 364

CHAPTER LI. RAILROADS: THEIR SERVICE AND GREAT INFLUENCE.

The Old-Fashioned Coach on Rails 365
Fire from the Sun Started It.................... 366
Meanwhile America was not Idle 366
Fanatical Prejudice cannot Kill a Good Idea 367
Cities Springing into Life and Getting Neighborly.. 368
Railroads that Span Continents 368
A Subject that Leads into Interesting Paths 369
Mileage and Cost 369
A Roadbed as Easy as a Rocking-Chair 370
Forty Different Kinds of Cars 370
From One Ton to Hundreds 371
Wonderful Speed Records 371
The Coming Era of Electricity 372
Safety of Billions 373
The "Railroad Question" and Brotherhood 373

CHAPTER LII. RAILWAY BLOCK SIGNALS.

Unhesitatingly Running a Risk 374
The Semaphore by Day and Lantern by Night 375
The Beginning of Modern Systems 376
The Block Tower Plan 376
The Ingenious Block System 376
How Trains Themselves Operate Signals 377
The Signal of a Signal 378

PAGE

CHAPTER LIII. CANALS.

A Log and a Pole 379
At the End of the Lake 379
Where Two Necks were Broken 380
The Largest Canal System in the World 380
A Fact that is Probably a Surprise 381
European Canals 381
Canals in Canada and the United States 382
A Route of Incalculable Value 382
A Saving of Thousands of Miles 383
Canal Mileage of America and Europe 384
A Twentieth Century Subject of Study 384

CHAPTER LIV. THE AUTOMOBILE.

When the Automobile was New 385
The Possibilities of the Automobile 385
The Evolution of the Automobile 386
The Machine with Many Uses 388
The Place the Automobile is Filling 390

CHAPTER LV. STEAMBOATS AND STEAMSHIPS.

When the Engine Shook the Boat to Pieces 393
The Water-Wheel Paddle and the Water-Churning Screw 394
Twenty Years Before Robert Fulton 394
The Immortal Fulton 394
A Slow Boat with a Rapid Name 395
River and Lake Navigation 395
The First Steam Vessel to Cross the Atlantic 395
The Era of the Ocean Liner 396
Ships that Can't go Down 397
How the Ship Gets into its Element 397
The Old Equipment and the New 398
How Steamships Promote Civilization 398
Increase in Speed and Power 399

CHAPTER LVI. THE ELECTRIC TELEGRAPH.

The Girdle Around the Earth 400
Early Experiments 401
Then Came the Artist-Scientist 401
Many Improvements Follow One Another 402
On Land and Under Sea 403
Sending Pictures by Wire 404

PAGE

Chapter LVII. The Atlantic Cable.
When Foreign News was Old News 405
The Tableland and the Cable Line 406
Triumphant Success of the Man who Never gave us. 406
And Now Marconi and the Wireless! 407

Chapter LVIII. The Telephone.
History of the Most Valuable American Patent 407
The Principle of the Telephone 410

Chapter LIX. Wireless Telagraphy.
Its History and Development 413
Scientific Construction 415

Chapter LX. Some Wonders in Building and Construction.
The Story of the Bridge 417
Concrete, the New Building Material 418
The Small Railway Bridge 419
The Cantilever Bridge that Crosses Great Chasms .. 421
The Graceful Suspension Bridge 422
Under-Water Traveling 424
How the Great Hudson River Tunnels were Built ... 425
Exciting Moment for the Underground Workers 425
How Sky-Scrapers are Begun 426
Tunneling Through Mauntains; Frozen Quicksands. 427
An Ingenious but Simple Device 427
The Greatest Canal in the World 428
New Methods of Excavation 429

Part VI.—Things Which Minister to Man's Comfort and Pleasure.

Chapter LXI. Modern Musical Instruments.
Antiquity of Musical Instruments 430
Some of Their Queer Uses 431
Classification of Musical Instruments 431
Wind Instruments 432
Wind-Instruments of Wood 432
Wind-Instruments of Brass 436
Keyboard Wind-Intsruments 439
Barbed String Instruments 441
Keyboard String Instruments 444

PAGE
Plucked String Instruments 447
Instruments of Percussion 448
Mechanical Instruments 449

CHAPTER LXII. GLASS.
What Glass is Made of 454
Melting and Cooling 454
The Process of Annealing 455
One Way in which Window Glass was Made 456
Three Ways in which it is Made 456
How Glass Vessels are Molded 457
The Manufacture of Cut Glass 457
The Flower of the Glassmaker's Art 458

CHAPTER LXIII. FIREWORKS.
Brilliant Rids to the Gayety of Nations 459
Danger in Amateur Fireworks Manufacture 460
Intense Heat of Pyrotechnic Materials 460

CHAPTER LXIV. AEROPLANES AND AIRSHIPS.
Realizing the Dream of Ages 461
Two Ways of Air Sailing 461
Think of Air as A Fluid 461
A Fluid Flows in Streams 462
You Push Against a Stream, or it Pushes Against You 462
It's the "Push" that Counts 463
How Air Actually Holds Things Up 463
What the Size of the Object has to do with it 464
The Angle also is a Factor 464
"Lifts" and "Drifts" 465
The Aeroplane a Counterpart of Air Forces 466
Various Types of Aeroplanes to Utilize Different Forces 466
The Secret is in the "Lift" 467
Naturally, the Lift is Regulated by "Elevators" 468
Two Elevators—Front and Rear 468
Studying by Model 469
Elevators that must be Directed 470
Seesawing about a Pivotal Point 470
Two Ways to Seesaw 470
Where "Warping" means "Tilting" 471
How the Balancing Planes Work 471

PAGE
For Calm or Storm 472
Overcoming "Drift" 472
Little Forces and the "Pivotal Point" 473
Getting a Good Start 474
The Monoplane 475
The Biplane 475
Two Deviations from the General Type 476
A Step Toward Flying that Young People can take . 476
The Machine as Light as a Bubble 477
A Force that Tugs Big Bubbles up 478
A Bubble that Becomes a Balloon 478
Evolution of "Balloon" into "Airship" 479
First Step in the Evolution is Change in Shape 480
Second Step—Putting an Engine Under it 480
Third Step—Making it go in any Direction 480
Three Types of Airships 481
The Flexible Airship 481
The Semi-Rigid Airship 482
The Rigid Airship 482
Big Liners of the Air Ocean 482
The Stopping of the Motor Makes the Stopping of the Story 483
CHAPTER LXV. MOVING PICTURES.
Catching Motion on the Wing 483
The Wheel-of-Life and What it led to............ 484
The Lens and the Film 484
The Making of "Records" 485
Real Actors and Dummies 486
Throwing the Light 486
Feeding the Machine 487
Millions of Patrons a Day 488
How the Whole World comes into View........... 488
CHAPTER LXVI. ILLUMINATING GAS.
The Making of Coal Gas 490
Purifying the Product 490
How Water Gas is Made 491
Names for Some of the Apparatus 493
Different Kinds of Gases 493
How Gas is Measured and Sold 494
Laws Fix the Standard 494
Uses for Gas 495

CHAPTER LXVII. ELECTRIC LIGHTING.

Arc Lamps 495
Incandescent Lamps 496
Tungsten and Tantalum Lamps 496
Sealing in the Conductors 497
Mercury Vapor Lamps 497
The Nernst Lamp 498

PART VII.—MUNITIONS USED IN WARFARE.

CHAPTER LXVIII.—GUNPOWDER.

When an Army was Blown to Pieces 499
The Greeks Blaze the Way 500
Finding the Easiest Way Out 501
Power Exerted both Backward and Forward 501
Fire Without Smoke 501

CHAPTER LXIX. GUN-COTTON.

A New Mixture with a Queer Name 502
Everything within Reach Flies in Pieces 503
Too Dangerous even to Experiment with 503
Something Found that is not quite so Touchy 504
A Thorough System of Bathing 505
How to Fire it Off 505
A Material Unsafe when "Safe" 506

CHAPTER LXX. GATLING GUNS.

Making War more Terrible 506
Firing Guns by Machinery 507
Three Classes of Machine Guns 507
How the Gun Goes Round 507
When Cartridges Jammed 508
Spreading the Bullets over the Field 509

CHAPTER LXXI. MODERN WARSHIPS.

A Race Between Guns and Armor-Plate 509
From Sails to Steam 510
"Pretty Stout Sheet Iron" 510
The Havoc of Horizontal Shell Fire 510
Hardly a Dent was Made 511
The First Battle Between Ironclads 511
A Period of Lethargy 512
The United States Wakes Up and Builds Cruisers... 512
The Growth of Battleships 513
Characteristics of the Battleship 513
Improvements in the Battleship 514
Then Came the Dreadnoughts 515

CHAPTER LXXII. TORPEDOES AND TORPEDO BOATS.

What a Torpedo Is 516
The Torpedo in the Revolution and the Civil War... 516
Not Waiting for a Vessel to be Blown Up.......... 517
A Most Delicate and Complicated Mechanism...... 517
The Torpedo Reconstructing the Navy 518
From the Little Steam Launch to the Great Destroyers 519
A Rather Disconcerting Danger 519
A New and Effective Destroyer 520

CHAPTER LXXIII. SUBMARINES.

Boats Made not for Travel, but for War........... 520
From Alexander the Great to the American Revolution 521
From the Revolution to the Civil War............. 522
The Holland Submarine in the United States...... 522
Submarines of Other Nations 523
Equipment of the Modern Submarine 523

PART VII.—THE STORY OF POLAR EXPLORATION.

CHAPTER LXXIV. NORTH POLAR EXPLORATION.

Ideal Explorers had only the Spirit of Adventure... 525
Henry Hudson, Boldest of Navigators 526
The Fate of Vitus Bering, a Dane................ 527
Navigators of the Nineteenth Century 528
The Magic of the North 530
The Fortunes of Captain John Franklin.......... 530
American Effort in the Polar Seas 531
Other Heroic Navigators 532
Expedition of Lieut. A. W. Greely............... 533
Doctor Nansen's Adventures 534
Robert E. Peary, American Explorer............. 535

CHAPTER LXXV. SOUTH POLAR EXPLORATION.

A Frown that is a Lure 536
Ice-Caps, Icebergs, and Howling Winds........... 537
Spasmodic Journeys to the Southland 537
A New Epidemic 538
Lieutenant Shackleton's "Farthest South" 539
A Glorious Race of Heroes 539

INTRODUCTION.

IT is Thought that has made all the difference! Reasoning from premise to conclusion—"putting two and two together"—has lifted man from the plane of the lower animals, has advanced him from a primitive state to that of civilization, has promoted him from a local, self-centered, individual unit to a being of dynamic power, capable of using, in common with other members of society, great world forces for the benefit of the race.

Discovery and Invention have resulted from experiment first evolved from careful study and thought, and partly by accident. From one basic invention—like the telephone—hundreds of other improvements, modifications of the original idea, have under the stimulus of thought been perfected and introduced. Thus one can understand how the discovery of mineral oil, at first considered to be a most inert substance, has by invention and thought been developed to so high a degree that its products are now universally used, notably that of gasoline, which when combined with an automatic electric spark, supplies a power never before dreamed of, making possible the traversing of the air in a birdlike fashion but on fixed wings with a facility and swiftness that is wonderful to behold.

And this brings us to another miracle wrought by the power of Invention and Discovery—the introduction of mankind from the darkness of the cave into the light of civilization. Life on the earth was at first a fight, single handed, against wild animals, the terrors of Nature, even against one's fellowmen. Now we work *with* Nature and *for* our brothers; but we do this only because the imperial Mind has learned how to use the forces of Nature instead of warring against them; and because every invention and discovery has its relation and inter-relation with all mankind.

And the dynamics of Invention! What limitations there were upon early man! How blind the unaided eye; how circumscribed the range of hearing; how utterly inadequate the feeble arm to gain a livelihood, inflict a blow, or protect the family, to say nothing of society! But what changes were wrought when Mind began its operations! The ear hears myriads of sounds and voices from afar. The eyes pierce infinite space or behold invisible atoms. The power of the arm, the hand, the foot, is multiplied a millionfold. All this, not by developing the senses themselves or the bodily forces; the wonder of it all is that Mind has taken hold of resources, outside itself, which have been stored up in preparation for this "far-off, divine event to which the whole creation moves"—civilization. And what "civilization" is the prelude of, it has not, even yet, entered into the mind of man to conceive!

A few, a very few, of the wonderful discoveries and inventions that have wrought such a revolution in the individual and in society, and that point the way to others yet more marvelous, are described in this volume. There can be no more fascinating reading or study than its record of Man's mastery over Nature and adaptation of her dynamic energies to the pleasure, comfort and needs of Mankind.

Frederick Converse Beach.

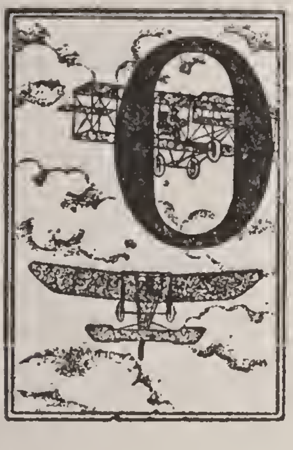
PART I.

THE CLOTHING OF MAN.

CHAPTER I.

The Story of Wool.

AN HUMBLE SERVANT.



OF all our domestic animals we should, perhaps, at first thought, name the dog and the horse as the best friends of man. But if we are to judge them by actual service, both these amiable creatures must give way to the mild and humble sheep, even though she does not inspire quite so much affection.

So vital a part has the sheep taken in the history of the human race that we name a whole epoch of its development after her—the pastoral epoch. That was the stage in civilization when sheep almost entirely fed and clothed whole nations, such as the Israelites before Joseph was sold into Egypt, and such peoples as now inhabit parts of Southern Europe and a great part of Asia.

A CIVILIZER—WILD BUT NOT WOOLLY.

Scientists can tell us almost exactly how the ancestor of the sheep first turned men from wandering savages into organized groups of self-reliant communities. Even before our very distant forefathers dared to live in the open, while they still hid at night in caves, they utilized the skins of wild beasts for clothing. Among the animals they hunted and killed was one which we call the argali, a cousin to the Rocky Mountain bighorn, but now inhabiting the mountain regions of Asia. The cave dwellers found the fur of this creature warmer than the furs of the other animals they hunted. At that time no animal, as yet, wore wool.

Presumably the cave-dwellers often captured the young of the argali and brought them home uninjured. In times of plenty these young argali were not killed but were allowed to grow up in captivity, perhaps to amuse the little cave-boys. The animals quickly became tame, and soon, in turn, begot their young.

Meanwhile, the cave men invented the bow and arrow, which gave them such an advantage in their encounters with the bigger and fiercer beasts, that they were able to come out of their caves and build rude huts in the open. But the bow and arrow also made game scarcer. So the men, perhaps during a famine, turned to their tame argali and made use of their meat and fur. While game grew even scarcer, the argali continued to breed fast, and gradually the men found that they could depend on them alone.

But, during this time, the argali ceased to be an argali; it became a sheep. At first it had had a hairy coat, like the goat to which it was a near relative. But close to the skin were soft, downy hairs which made the animal's coat unusually warm. As generation after generation was born in this semi-captivity, the long straight hairs fell out and the downy wool grew longer and thicker. That was the first wool. Now the domestic sheep is quite unlike its cousin, the Asiatic argali of today.

So, from wild hunters, almost as fierce as the beasts they hunted, men became sheep-herders; they entered into the pastoral epoch. The quieter life bred in them some gentleness, and gave opportunity for the development of the primitive human virtues. They had more time for thought. It could not have been long before they learned to make use of the wool of the sheep without killing the creature. They cut it off and matted it together, as do the shepherds of many semi-civilized countries today. Afterwards came spinning and weaving.

AFTER WOOL, WEAVING.

At any rate, long before historical events were recorded, the wool of the sheep was twisted into threads and woven into garments. Except possibly tanning, it was the first manufacturing art. For many centuries wool was the clothing of the masses, until the cotton-gin put cotton in its place.

But, in spite of the cotton-gin, the wool industry must always hold an important place in cold and temperate climates. Today it is one of the chief, as it is one of the oldest, of American industries.

The American Indians have never reached the pastoral stage. They are still hunters. So the sheep had to be imported, though the Rocky Mountain bighorn might in time have been domesticated. In 1607, Virginia brought the first sheep into the country. In 1633, Massachusetts also imported sheep, and, to keep them protected from Indians and wolves, they were herded on an island in Boston harbor. By 1642 there were a thousand sheep there.

AMERICAN WEAVING STARTED BY A MINISTER.

But American wool industries really began in 1638, when Ezekiel Rogers, a Puritan clergyman, was expelled from England and came to Massachusetts with his whole congregation, most of it composed of weavers. They founded Rowley and set up the first woolen mill there.

Now there are over twelve hundred modern factories throughout the United States, employing one hundred and eighty thousand people. New England still leads with the largest mills—in Providence, R. I., and in Lawrence, Mass. To supply all these mills, about sixty million sheep are sheared a year, producing over three hundred and twenty-eight million pounds of wool, and, as even this vast supply is not enough to clothe the nation, about two hundred and sixty-four million pounds more are imported from Australia and South America.

"ALL WOOL" AND "PART COTTON."

The bulk of the industry, of course, consists of the weaving of cloth. We know that much of this cloth is "part cotton," but even where the familiar expression "all wool" may be truthfully applied, the superior quality of the goods is by no means assured. There are grades of wool not so good as cotton. The best is from the Merino sheep, originally bred in Spain, and several breeds of English sheep, from which the famous Tweed suitings are made. But even the fleece from these superior breeds is not of one quality; that which comes from the throat and the belly is always inferior to that shorn from the shoulders and the flanks. The different grades must then be established by assorting. A pound of the back or shoulder fleece from the best breeds can be spun into one hundred miles of thread.

The most expensive wool in the world does not come from the sheep at all. It is the Cashmere goat which gives that fine fleece from which are made the famous Cashmere shawls, some requiring the lifetime of one person in their making. But one goat gives only three or four ounces of this valuable material. Mohair, also classed as wool, is really the hair of the Angora goat; in America a million pounds a year are produced.

AUSTRALIAN WOOL-SORTERS AT WORK.—Australian Wool is the finest in the world, and enormous quantities are exported annually to other countries.

CHAPTER II.

Silk: Its History, Manufacture and Uses.

THE LITTLE SILKWORM AND HIS HOUSE.

SILK begins, as every one knows, with the little silkworm, an infant of the moth family, and any child fortunate enough to be within reach of a mulberry tree can watch it spin its wonderful cocoon. Silkworm eggs can be bought in any large city, and if they are kept in a warm, dry place, where the air is pure, they will presently hatch, and moult four times in less than as many weeks, eating voraciously of the fresh mulberry leaves provided for them. In the last ten days of the first month they spin their silk, which comes out of two little openings like nostrils, and is sticky, like a strand of a spider's web, so that the two threads, or "filaments," join into one. First, an outer skin, web, or shell is woven, the threads somewhat rough and uneven; inside that, bending and twisting in every direction, the little creature wraps itself in finer silk; and inside of all is a still more delicate silken chamber which will keep out both cold air and water. Sometimes the cocoon is finished in a few hours; oftener it takes two or three days.

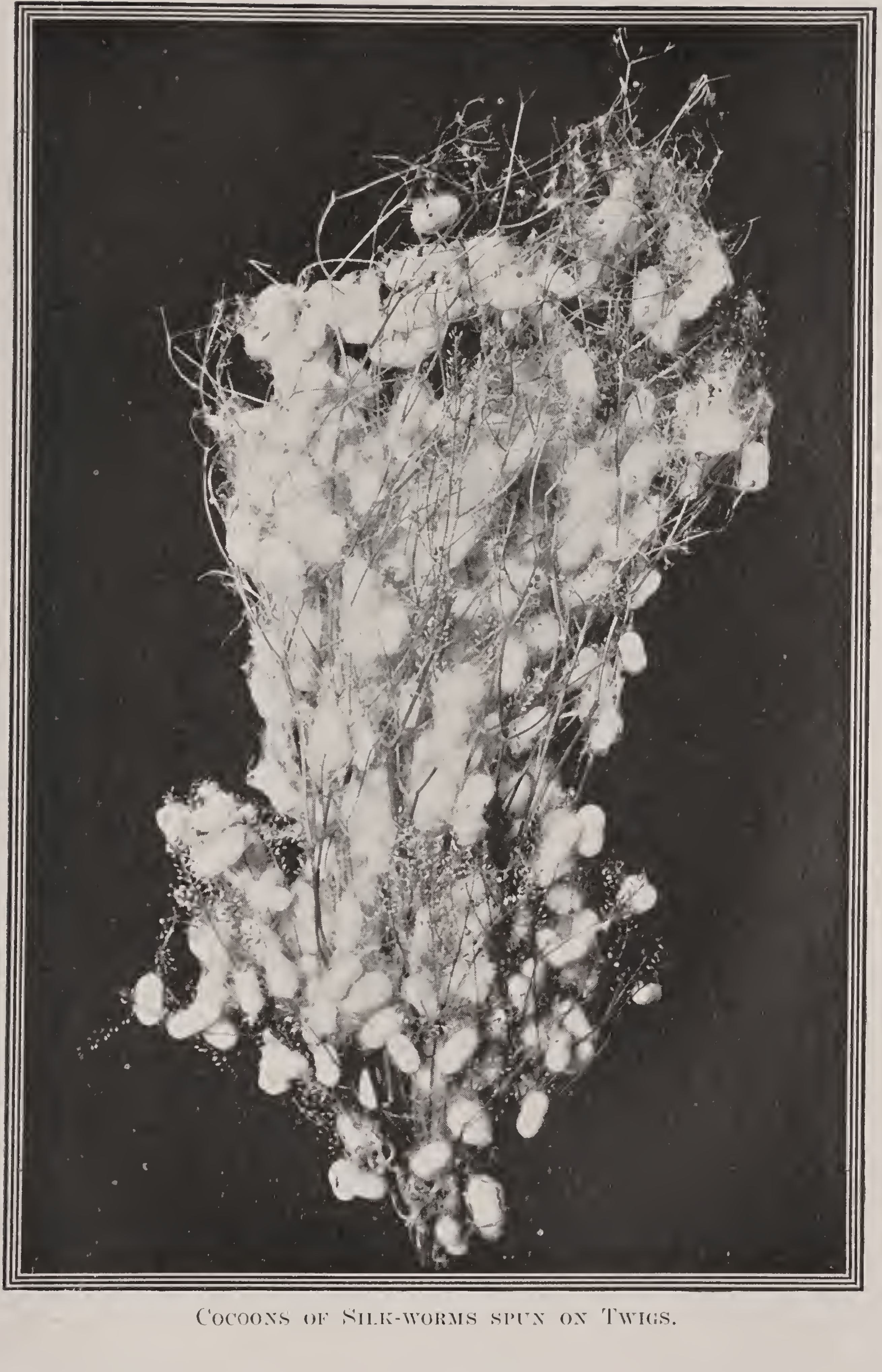
The Chinese say that the silkworm belongs to the "yang" or "Superior Principle" of nature, and therefore loves fire, hates water, and eats without drinking. Smoke, strong smells, foul air, dampness, or the jarring of noisy work, such as pounding or machinery, are all bad for silkworms.

The silk thus spun is of a golden yellow color, and, if left alone, the worm will become a moth and eat his way out. But, in silk manufacture, of course this does not happen. The cocoons are baked in an oven, or steamed, or put in water heated to about two hundred degrees. The floss on the outside of the silkworm's wee nest is used for various kinds of silk goods which do not need an even, long, fine thread; when this has been slipped off, the unwinding and "reeling" of the true silk begins—one thread, seven hundred and fifty to one thousand one hundred and fifty feet long. The best cocoons have the least floss.

The filament spun by the silkworm is covered with a gum-like stuff, which hardens like paste. To soften it and make the silk possible to unwind, the cocoons are put in a bath of hot water, and the girl in charge dabs at them with a tiny whisk, to find the end of the silk. Sometimes the Chinese use their fingers for this, but oftener a whisk of bamboo split at the end. When the end of the silk has been located, the winding begins, and the silk wound on reels is known as raw silk. When taken off the reels it is made into bundles, which in China are called "books;" in other countries, it is twisted into hanks like yarn. From three to thirteen of these filaments are wound as one thread, which shows how delicate the spinning of the silkworm is. This raw silk is not twisted at all, but the gum hardens a little as it is reeled and makes each strand a kind of thread.

WHERE SILK FIRST CAME FROM.

There is a slang phrase, "first-chop," meaning "the best quality," which is probably a left-over from the old days of the East India trade, when ships from China and Japan came into Boston and New York laden with silk and tea. "Chop" means the official stamp put on such goods, and the different grades of silk in the Chinese trade are known as "chops." They sometimes have very quaint and pretty names, such as "Mandarin Duck," "Almond Flowers," "Black Lion," "Blue Elephant," and so on. So the old-time merchants said silk was "first-chop," when they meant it was of the finest sort; from that they



Cocoons of Silk-worms spun on Twigs.

called other first-class things "first-chop," and, finally, people took up the phrase who knew nothing about silk or Chinese "pidgin" (business) English.

You cannot go very far in silk manufacture without coming on traces of the Chinese, for they were making silk thousands of years ago. Chinese historians say that the wife of the emperor Hwang-ti, about 2,600 B.C. first unwound the silkworm's cocoon. In the twelfth century, Eastern merchants brought silk-weaving to Sicily, and the Moors introduced it in Spain; but France did not take it up until about the middle of the sixteenth century, and England was still later in founding silk factories. Italian silk-weavers were the first in Europe, and Pippa, the little silk-winder in Browning's poem, was one of the girls whose light touch, in every Italian city, disentangles and reels off the silk from the cocoon.

It takes from two thousand to two thousand five hundred silkworms to produce one pound of silk. From the Chinese silkworm we procure most of raw silk in the United States but there is an East Indian silkworm as well. The silk of India is less fine, and some of it is made into what is called "Tussah," or "Tussore silk," from "tasar," a native word. This is often sold in the natural color, cream, buff, or orange.

HOW SILK DRINKS WATER, AND WHAT COMES OF IT.

Very early in the history of the silk business the makers and merchants met a curious difficulty. Silk has a peculiar aptness for absorbing damp, and, as it is sold by weight when it is in the raw state, a merchant often found that he was paying for more silk than he got, or, in other words, he was paying for silk and getting silk-and-water. Sometimes a bale would be sold as being of a certain weight, but, after it had stood for a time in a dry warehouse, it would fall considerably below that weight, which of course led to many hot disputes. The fact that raw silk is generally reeled in the rainy season did not help matters. Neither could the merchant demand that the silk should be absolutely dry, for it will take in moisture from the air in anything short of the heat of the Sahara. Finally, a conference was had in Turin, in 1750, and it was decided that the proper amount of water in silk should be eleven per cent., and "conditioning houses" were founded, where good judges could examine the silk and decide whether the moisture was more than normal. The allowable amount of moisture in cotton is only 8½ per cent. Silk can contain fifteen per cent of water without appearing to be moist at all, and at its dryest it contains eight per cent.

WHAT THE BRITISH THOUGHT ABOUT SILK IN AMERICA.

The history of silk in America dates back to the early settlement and colonial period. At the time America began to be really settled, the silk factories of Europe were in full blast, and doing a magnificent business; and the kings of both France and England regarded this country as a splendid field for raising silkworms and supplying raw silk. In 1718, the cultivation of silk was introduced into Louisiana. James I. tried his best to start the making of raw silk in Virginia, but tobacco proved more profitable. There were even fines for planters who neglected to plant mulberry trees, and premiums for those who did, and bounties were offered for raw silk. In Georgia, a settler who did not plant one hundred mulberry trees to every ten acres of ground was liable to have his grant revoked. But, like all kings who undertake to make laws for colonies which they have not seen, and about which they have a very hazy idea, the English kings overlooked the fact that to make a business profitable you must have the right kind of labor. The rude, unskilled labor of the South was not adapted to the rather delicate job of making raw silk. In the North, however, conditions were a little better, for many a farmer's wife could reel off some silk on her spindle when she had the spare time. In 1790, Connecticut took up the work, and fifty thousand mulberry trees were grown near New Haven, and fifty families were engaged in raising silkworms. But this was after the Revolution.

The British lawmakers had no idea of allowing the American colonies to get any of the profit which might come from silk factories. They laid heavy duties on machinery, and all such things for American use. What they wanted the colonists to produce was raw silk for English factories to make up, thus keeping the work all in the family instead of buying raw silk from China or Italy. But, as soon as the colonists began to manage their own affairs, the manufacturers of New England woke up to the profit in the silk business. Sewing-silk was made in this country about a hundred years ago, though the first Jacquard loom, for weaving silk, was not brought over till 1825. When the factory furnished a market close at hand, the raw silk began to appear. In 1839, five tons of raw silk were made in and about the little town of Mansfield, Conn. Ipswich, Mass., also had its silk factories. Raw silk was made in South Carolina, in a German colony near Savannah, and in Pennsylvania.

HOW THE RAW SILK IS WORKED UP.

After the raw silk has been produced, the "silk thrower" begins his work. The "throwing" of silk means twisting the fibres, as all thread, to be woven, is twisted; but silk must be differently treated from cotton or woolen, because, instead of being fine, short fibres twisted together, it is one long thread or filament, and the fewer breaks there are in this, of course, the stronger and better the silk will be. Floss silk is carded and twisted like cotton, for that is all made up of short, uneven threads, but the best silk, from the middle wall of the cocoon, being one long, even thread, the most skilful silkmakers keep from fraying or breaking it in the weaving. That is one reason why silk is stronger than any other woven fabric—when it is pure silk. A thread of silk is said to have a strength one-third as great as that of the best iron wire. You can easily see this by comparing a bit of sewing silk and a cotton thread of the same fineness. The cotton will break easily, but the silk may cut your fingers. The use of the longest fibers is called "long spinning." "Short spinning" or "cut silk spinning" was an old method in which the silk was all cut and spun like cotton, but silk made by this process was not nearly as beautiful, durable, or lustrous as the modern "long spinning" will produce.

In the old-time factories, over half the silk was wasted. Little or no use was made of the floss silk or the broken ends. Today every bit is put to some use. Fringe, silk buttons, silk-and-cotton and silk-and-woolen goods can all be made with these rough, uneven fibers.

The ribbon factories of the best class use the finest silk, and good ribbon is today of the best silk one can find, the strongest, and most beautiful.

After the "thrower" or "throwster" has finished his work, the silk is spun and woven very much as linen or cotton would be except that extra care must be taken to keep it clean; for silk attracts dirt as it does water. Some of the best ribbon factories are as neat and trim as a lady's boudoir.

Almost no raw silk is produced in America at present. We get 25 per cent every year of all the raw silk made in the whole world, and use it in our silk factories. We have more than twenty-seven thousand power looms for broad-silk weaving and six thousand for ribbon weaving, and American mills now supply two-thirds of the home market for silk. We get some silk goods from Japan and France, and a small quantity from China. In Japan most of the silk is woven on hand looms, of which the country has six hundred thousand. They can be purchased for only $2.50 a piece, and, as a power loom cost $250, it is only in the large cities of Japan that we find factories using power looms. The best Japanese and Chinese silks stay at home, and many of the finest designs are not seen outside those countries. A great part of the Japanese silk business is the weaving of obis, or sashes, and the kimonos and wraps of Japanese women are of beautiful, soft, heavy silk which we do not see here. It is brilliant, elastic, and durable.

The trouble with most of our silk, especially the cheaper grades, is that it is "weighted," that is, it has been through a chemical bath which makes it heavier but fills the fabric with tiny particles of mineral. These cut the silk and help it to wear out. When silk has been soaked in acetic acid and then dried, it makes a peculiar rustling, grating noise which a silk-merchant calls "scroop." But some people prefer silk that rustles, and do not know the difference between a rustle which is proper to silk and one which is merely "scroop."

THE SILK LOOM MAY GET RHEUMATISM.

A great deal of the beauty of silk, also, depends on the perfection of the loom and the skill of the weaver. An old weaver will tell you that a silk loom can get rheumatism, just as a person can, and requires quite as careful attention. He will also tell you that it has to be kept cleaner than any other loom, because, if there is a trace of oil anywhere, the silk will be sure to catch it.

Our ribbon mills are only about twenty-five years old; as late as the seventies, most of our ribbons came from Europe. Today hardly any of them do, except a few sorts which are woven in France, from special designs.

HOW SILK FRETS, AND THE RESULT.

A curious quality that silk has is that of wearing itself out. As diamond will cut diamond, so silk will cut silk if two silk folds rub against each other. And if the silk is "weighted" with mineral, of course this is all the more sure to happen, so that a silk plaiting, or ruffle, will rub itself into holes in a very short time. However, better and cheaper silk is made today than ever before, and in time, perhaps, these false silks may disappear from the market, as have some other shoddy things, and for the same reason—because honest goods can be made cheaply, and people like them better. We are beginning to find that the cost of a workman's time amounts to more in manufacturing than the cost of the material, and it takes about as much time to make a sham piece of goods as a real one.

SOMETHING THAT LOOKS LIKE SILK, BUT ISN'T.

A kind of material has come on the market within the last ten years, which is called mercerized cotton, and looks as much like silk as anything could that is not silk. It is named after John Mercer, an Englishman, who was born in 1791 and died in 1866, and who made calicoes. He discovered a way of treating cotton to a bath of potash or caustic soda, which made the fibers shrink. After the bath, the threads are stretched upon a frame, and you may judge of the effect by pulling a bit of rubber band in your fingers and seeing how much finer and smoother it becomes. These fine, smooth fibers are then spun and woven as ordinary cotton is, and besides having more luster they take color much better. Silk will take dye more beautifully than anything else will, and mercerized cotton can be dyed to be nearly as beautiful as silk.

HOW SILK GETS ITS BEAUTIFUL COLORS.

The dyeing of silk is a business all by itself, and there is no end to the wonderful combinations dye-stuffs will make. Sometimes goods are dyed in the skein, that is, before they are woven; the dyeing of any silk woven in a solid color, or in a pattern where the warp is of one color and the woof of another, could be done in this way. A kind of silk very much favored years ago was known as changeable silk, and was made of two colors of about the same blend, like rose and gray, green and brown, or blue and green, woven together in this way. Dark silks can be dyed without having been bleached, but, for light colors, the silk must be treated with sulphur first, for the color of raw silk is naturally so yellow that it would change the shade of the dye, and, instead of a pale rose pink, we should have quite another color. Besides the dye, a ''mordant'' or a chemical to set the color always has to be used, but silk needs less mordant than cotton. Black, for instance, can be made by using logwood dye with a mordant of iron. A good silk, dyed with vegetable dyes, will never fade, though the color may soften a little in the course of time. A queer fact about some fabrics, especially some blues, is that they will fade if worn in the sunshine for several months, and then, after being hung away in a dark closet for the winter, will get back some of their color. Dampness probably has something to do with this, as well as the action of the light. A great advance has been made lately in the work of dyers, so that one can often buy even a very cheap stuff without finding that, in a few months, it loses much of its beauty by fading. Black dye seems to have a peculiar tendency to rot silk, and one must buy a better quality, in black, to get the same wear out of it that one would get out of a lighter color. One reason for this may be that a lighter silk shows its class more plainly than the darker ones do, so that the poor silks may be used for dyeing in dark colors. In the old times, indigo was used for blue and cochineal for red, and various sorts of herbs for other colors; today, a large proportion of the dyes used in every line of work are aniline dyes, made from coal-tar; they are of every color that can be imagined and very easy to use, but not very good for the fabric they are used on.

THINGS THAT ARE MADE OF SILK.

Besides silk and ribbon, there are, of course, any number of fancy kinds of silk goods, either all silk or made of some mixture of silk with cotton, linen, or wool. Chiffon, silk mull, and gauze are light, delicate, and veil-like stuffs made of silk or silk and some other fabric. Grenadine is a thin material made of silk and light wool. Chantilly lace is made from silk; so is blond lace. Often, where silk is to be knitted, as in silk underwear, stockings, or mittens, the thread is part cotton. Artificial silk has no silk in it at all, for it is made of some sort of fiber or pulp soaked in gelatine or gum; there are several different ways of making it.

Silk threads are as different as woven silk is. Sewing-silk is made of fine, long filaments; embroidery-silk is called ''floss-silk'' and is generally made of floss, with very little twist, so that it will lie flat and shape itself to the work. Silk twist for making buttonholes is as strong as a cord. But silk is so elastic that in sewing with it great care must be taken in fastening it, or it will rip out much more easily than cotton. For this reason, in spite of its strength, we do not use silk thread much in machine work, such as tailoring.

If you count all the ways in which silk is used in our clothing you will see that the little Chinese silkworm is an important creature. In fact, a lady could be dressed in silk without using any other material, except for the soles of her shoes, and, in China, Mandarins and many other people are so dressed.

CHAPTER III.

The Great Linen Industry.

A TRADE THAT GOES BACK THOUSANDS OF YEARS.

LINEN-WEAVING is one of the oldest of trades. Two hundred years before Christ, Egyptian linen was famous, and, in the British Museum, there are pieces of this fabric that have one hundred and fifty-two threads of warp to the inch, and seventy-one threads in the weft. This linen was made in a hand loom, set upright before the weaver, and the weft was put in with a long needle.

WHERE MISTS ARE A GOOD THING.

It is a curious fact that, if we note the countries where fine linen was woven in old times we shall find that they were always countries where the air was soft and moist. Irish linen "Hollands" and Egyptian linen were all woven in such damp, soft air. In linen factories today the air has to be kept damp, and this is now done by mechanical means of one sort or another. What is more, the heat has to be about the same all the year round, to get the very best weaving. Of course, some sorts of cloth can be woven anywhere, but fine, white linen cannot.

A NEW KIND OF LANGUAGE.

Reading a book on weaving by machinery, or hearing the talk in a factory, is like trying to understand a new language, for every part of the work has words of its own which no one but a weaver would understand. They have, too, an odd clattering sound which reminds us of the clickety-clack of machinery. Heddles, tappets, wypers, cops, lease, pirn, slay, batten, heald,—almost all of these names are old English, Saxon, or Scotch words which weavers have used for hundreds of years. And the men and women who work in the factories of Belfast and Lancashire are the great-grandchildren of the weavers or "websters" of the old days when the web was woven in the loom-room of the weaver's own house.

A MACHINE THAT CAN DO EVERYTHING BUT TALK.

It was once said of a very ingenious machine that it could do everything but talk, and the machines used in a linen factory certainly seem to have almost human intelligence. The first great invention was Arkwright's spinning-frame in 1767, and the next was Jacquard's loom, which made it possible to weave figures into the cloth, by machinery. Jacquard was called to Paris in 1809 by Napoleon and presented with a medal for his invention, which saved one man's labor on each loom in a weaving-room. Arkwright was knighted by George III. In the eighteenth century the wonderful inventive powers of men seemed to be just waking up, and the world was passing from an age of hand-work to one of machine-work.

The first step in weaving linen is to stretch the warp on the loom, and this is done by a machine specially fitted for the purpose. Sometimes the thread comes to the weaving-room wound on bobbins, and sometimes in hanks; there are machines for winding it from either. There is a steel gauge for "spacing" the threads and making the weave coarse or fine; this is called a reed, and in the earliest looms it was really a reed. In Irish linen there are about two thousand four hundred threads to a forty-inch reed. The gauge is always set a little wider than the cloth is to be, because the cloth shrinks while being woven. You can see that for yourself in darning a large hole in a stocking; if great care is not taken it will surely pucker.

One great improvement that has been made in the last hundred years is in the width which can be woven. "Broadcloth" when first woven was only twenty-seven inches wide; but there are now looms which weave "double width" by an ingenious arrangement of the machinery. Every bit of the machinery used today in weaving is a product of the thought, inventive genius, and countless experiments of many skilful and thoughtful workmen, most of whose names, even, we do not know. And as one man after another saw how to do some particular thing better, or quicker, or with less effort, the machine was changed just a little, until the loom of today is like a living creature.

ANOTHER INTELLIGENT MACHINE.

There are machines, too, for winding the thread on the "cop," the spindle, and on the shuttle, or "pirn." The shuttle is a rectangular piece of hard wood, polished and tapered at the ends, and tipped with iron. Boxwood is often used for it; cornel wood is liked by some weavers, and is not so heavy. Every shuttle in a loom must be exactly the same as the others, or the weaving will not be even. For fine linen the shuttle must not weigh over twelve ounces. The flashing of the shuttle through the threads, across the loom, is called a "pick," and one hundred and sixty-five picks to the minute is a good average speed for a linen-loom.

SOME ODD FACTS ABOUT LINEN.

The plain weave, one thread over and one under, as in darning, is the strongest weave possible, but there are all sorts of fancy weavings, which you can see in any drygoods store. In a twilled cloth, the shuttle moves one thread to the right or the left, at every "pick." By taking two or more threads at a time the shuttle will form any sort of pattern, as you can easily see by picking a bit of figured table linen apart and finding how the threads run. A skilful mender can imitate these weaves with a needle and ravelings, in darning a hole in a table-cloth, so that no one can see where the hole was. A corded weave is made by two or more of the warp threads being worked as one, wherever the cord is to show.

In making a design for weaving, paper is ruled into small squares, and the space between the lines is marked off to show the designs.

In early times the ell was the common measure for linen, and, oddly enough, it was forty-five inches in England and thirty-seven inches in Scotland; but now the yard is used everywhere.

Before the weaving is done the warp-thread is "dressed" or "sized," and the appearance of the linen will greatly depend on the way this is done. The dressing is made of flour paste, or sometimes of Irish moss, or a mixture of moss, with glue or paste. It lays the loose threads and makes the warp-thread harder, firmer, and easier to handle. A skilful manufacturer can often manage this dressing so that the linen looks much finer than it is; so wise old housekeepers will tell you that the best linen to buy is that which has "a round thread, and very little dressing." This shows that the linen has not been treated with any chemical or worked on to make it look better, but that it is just what it seems to be. The best linen is not stiff and glossy, but firm, and fine, and well woven.

Bleaching, after the linen is woven, is done best in the open air, the web being spread on grass and kept wet. This is a special reason why Irish linen is so good—for it is manufactured where the mild, soft climate makes it possible for much of the work to be done out of doors. But the web must be left out on the grass two or three days at a time, and tended carefully, which makes the process rather costly. The more common way of bleaching is by chloride of lime, in which the web is dipped. It is starched with wheat flour, and sometimes fine clay or other mineral is added to give it weight; this, of course, is not very good for the linen, but it makes a poor quality look like something better. Calendering is another finishing process the linen has to go through and it is done by passing the linen over cylinders to make it glossy.

Almost every country has a special way of folding a web of linen. After it is folded, in these days, it is put through a hydraulic press, where it is subjected to a pressure of from ten to a hundred tons; then, after the label is pasted on, it is ready to be packed for the market.

NAMES FROM ACROSS THE SEA.

There are many different kinds of linen, and the names often have a curious story. Cambric is called so from the French town of Cambrai, the Flemish name of which was Kameryk; and chambray is named from the same town. Batiste is linen or cotton lawn, named after the Frenchman who first made it, and lawn gets its title from Laon, the French town which used to be famous for it. It was first used for bishops' garments. Buckram was originally made in Bokhara, for the foundation of a particular kind of carpet. Drilling is a three-twilled cloth named from the Latin word trilex, which means three threads. Osnaburg is a coarse cloth of linen and tow, first made in the German town of Osnaburg. Crash is from the word crass, which used to be a common word for coarse. Linsey-woolsey, for petticoats, is a cloth which English cottagers made of mixed linen and woolen.

WHEN LINEN IS NOT LINEN AT ALL.

A great deal of the linen in the stores today—indeed, most of it—is not linen at all, but cotton; and some of it is a mixture of cotton and linen. Very little pure linen is sold, and if you see table-cloths or sheets advertised as ''linen,'' at a low price, you may be sure that there is no flax in them. Cotton wears very well when it is properly woven and finished, however, and for some uses is quite as good as the pure linen would be, if not, indeed, better. One peculiarity of good linen is that the older it is the finer it seems to become. As long as there is a scrap of it left, it is useful. In the old days, before absorbent cotton was invented, every woman had old linen laid away, to scrape for ''lint,'' which was the very best thing for a cut or wound. Linen thread, as you can easily see by trying to break it, is much stronger than cotton; fine embroidered linen will wear almost indefinitely, and anything made of it will keep its shape.

CLOTH THAT HOLDS ITS OWN.

One great advance that has been made, within the last thirty years, in the manufacture of all sorts of goods, but especially cottons and linens, is that they are finished so that they hardly ever shrink. When our grandmothers began to keep house, the shrinking of all kinds of garments was one of the most troublesome things they had to contend with. But nowadays in the finishing, dressing, starching, and other processes to which every material is subjected in the factory, the web is inclined to shrink all it ever will before it reaches the store, and those who deal in ready-made clothing have learned that it sells better if the cloth has been shrunk before being made up.

HOW TO HAVE DESIGNS UPON LINEN.

Still another great advance which has been made since the day of Jacquard is in the variety of designs. In old table-linen you will hardly find any but the simplest design—a spot, a stripe, a check or a diamond. Today even private families have linen woven to order, and hotels of the best class always have their table-cloths and napkins woven with their special patterns, with the name or device of the hotel in the center. When an English king is crowned, special table-linen is designed in memory of it. The looms of

Belfast, Lancashire and Dundee were busy for many months preceding the coronation of King George, turning out the "coronation linen" of 1911. A pattern which came over to this country at the time of King Edward's coronation had a center woven with the English lion and unicorn, and a border of intertwined thistles, shamrocks, and roses. Table-cloths used to be woven in long webs and cut off at the desired length; now they are woven in all sizes, with a border all around, and a pattern in the center. They are to be had even in circular form. There seems to be nothing that the wonderful, intricate, ever-busy loom and the weaver behind it cannot do.

CHAPTER IV.

Lace-Making.

A LOVELY ART.

LACE-MAKING is not a very old art compared with weaving, embroidery, or leather-work; the first lace that we know of was made in the fifteenth century, in Italy and Flanders; both countries claim to have invented it. A hundred years later, the laces of Holland and Belgium were a source of great wealth to those countries, as they still are, especially in Belgium, and France took up the work as alertly and skilfully as it did every other handicraft. In 1666, thirty Venetian women came to Alençon and were the first workers in a factory founded by Colbert; the lace there was known first as point de France, and then as point d'Alençon. A little before this lace-making had begun to flourish in England, and the Venetian, Milanese, and Genoese laces had long been famous. Every sort of lace which has ever been made in any country is still made; but many of the most famous kinds are now imitated by machinery, and sometimes the work is done partly by machinery and partly by hand.

The convents have been the great teachers of lace-making, and some of the finest lace is still convent-made. In Europe, where convents care for a large number of the orphan children in nearly every country, the nuns often teach foundling girls to make some special kind of lace, or perhaps only a part of some special kind, and they become very quick at it. As they get no wages, but only their living, lace made in this way can be sold cheaper than is possible when made by women who must pay rent and living expenses, and save something from their earnings.

MANY VARIETIES OF LACE.

Almost every kind of lace is made in one of two ways. That done with the needle, on a parchment pattern, being called needle-point, while laces made over bobbins, on a pillow, are known as pillow-laces. Some of the Spanish and Italian laces are called cut-work, because they are of fine linen cut into intricate designs, which are connected by lace stitches, and often the linen of the designs is embroidered. Such lace is mostly used for altar-cloths, copes, and other church vestments; but it is not true lace, which is all made of thread. Irish lace is either crocheted, or, in some special kinds, is darned on net; in real lace, however, this net foundation is made over bobbins on a pillow. The bobbins, which were in the old days little bone needles, are stuck into a cushion through the pattern, which is of parchment; and the thread is wound around them, being twisted and crossed so as to form a fine network; over this a pattern is woven with thicker thread. This is the way in which all the real network laces are made. Point lace is made by many American women, somewhat after the manner of the lace called Battenberg, but, instead of the braid being bought, it is made by the lace-worker herself; and, instead of the pattern being cambric, it is parchment or cardboard—the former being preferable.

SOMETHING OTHER THAN HANDS THAT CAN MAKE LACE.

The first attempts to make lace by machinery took place at Nottingham in England, where the largest English lace factories still are; but the first real success in machine-made lace was won by Heathcoat in 1809. It caused a great deal of excitement among the lace-workers, who saw that such a machine could make lace much faster and cheaper than they could; and Heathcoat was finally obliged to take his machine into Devonshire. Of course, wherever machines have been introduced, many of the hand-workers learn to use them, but the older workers, who have to depend upon their work to support their families, cannot so easily learn a new trade, and often they are not wanted because the younger ones do the work better; the result is that such a change works a great deal of hardship for awhile. In fact, the machine-made laces have almost driven out the hand-work in England. This is a pity, because no machine can make lace which is as beautiful as the very best of the hand-made laces; and when the work is done by hand, at home, as it usually is, there is a chance for more originality and improvement in the designs. Moreover, the women who perform the work do not have to leave their families and go into factories, but can earn something at home, and teach their daughters as well.

A FINE DEED OF ENGLISH NOBLEWOMEN.

For all these reasons, many Englishwomen of wealth and rank are now doing what they can to encourage lace-making. Both in Devonshire, where

Honiton lace is made, and in the Midlands, the home of Bucks point, a lace rather like Mechlin, they have started schools to teach lace-making, and formed societies which help to sell in London the laces made; for of course the lace-makers cannot often go away from home to find their market. When this movement began in the Midlands, in 1897, only sixty lace-workers could be found who knew how to make the old Bucks point, and most of them were women over sixty years old; now there are more than four hundred workers. Some of the wives of English noblemen teach classes in lace-making themselves. In Somerset, the County Council pay the fees of the six best workers in the Taunton lace-classes. And so, in one way and another, lace-making is being revived. Lace-making by hand is so long a task that a real lace collar is costly, and, unless there is some such arrangement to bring together customers who can afford to buy the lace and the cottagers who make it, there is no money in it for the makers. They earn only a few cents a day at most, but living costs less in Europe than it does here, and even a small wage is better than nothing.

One reason why old lace is so beautiful is that linen thread should be used instead of cotton; and the English women, who had interested themselves in reviving the art of lace-making, at first found great difficulty in getting linen thread. The thread manufacturers said that, as there was so little demand for it, they could not afford to make it. They were soon convinced, however, that a new and growing market was being created for lace, and linen thread was supplied in abundance.

THE BEAUTIFUL BELGIAN LACES.

In Belgium, there are about fifty thousand lace-workers, and every district has its special kinds of lace; all the women in one village, for instance, make needle-lace; in another, pillow-lace. Of late years, lace-making schools have been started, and the children learn in these to make whatever lace they like; but in old times, each mother used to teach her daughter the one or two kinds of lace she herself knew. The famous Belgian laces are Mechlin or Malines, and Valenciennes. In one district of Belgium the lace-making business was almost ruined by having the agents of a factory come in and induce the lace-makers to work only for them and make only the coarse lace which they found more profitable.

LACES OF OTHER RACES.

Calais has sixty thousand lace-workers and about six hundred and fifty factories. Lace-making employs about one hundred thousand people in the factories in northern France, and about as many more work outside the factories, either making lace, or finishing what has been partly made by machine. The process consists of clipping the ends, and perhaps putting in lace stitches on a groundwork made by machines.

The only English lace ever successfully imitated by machines is Torchon, which can be made so perfectly as hardly to be distinguished from hand-work. But there is a difference; and one respect in which real lace is unlike that made by machinery is its softness; in washing it should never be starched, and it would better not be ironed but only pulled into shape.

One thing which has a great deal to do with the choiceness of very fine laces is climate. In countries where the air is soft and moist, as it is in the Low Countries, in Ireland, and in misty England, better lace is made than elsewhere, and finer thread can be used. The fairy-like threads are softer and do not tangle. This is true of any sort of work where fine linen thread is used.

SOME FAMOUS OLD LACES.

Some of the most famous kinds of lace are as follows: Alençon lace has a very fine net ground with sprigs or other designs woven on it. Blond is a silk lace, which used to be sold unbleached, so that it was cream colored. Chantilly is a blond lace without any lustre, and the flowers are in openwork on the net. Cluny is a French net lace, with the ground in squares similar to mosquito-netting, instead of having a six-sided mesh like some of the finer laces, and the figure is darned on this square net. Duchesse is a Belgian pillow-lace, with a rich design outlined in fine cord, producing a raised effect. Guipure is any lace with no net ground, the pattern being connected with lace stitches done with the needle. Mechlin has been called the prettiest of the laces. It has a net ground, and the flowers are in thread with a flat effect like embroidery. Spanish lace is a black-silk lace with large designs of flowers, made mostly in Flanders for the Spanish market. Another sort of Spanish lace is more like drawn-work; it is made in Spanish convents, and when the Spanish came to America, the nuns taught this work in the convents here. It is often called Mexican drawn-work. Valenciennes is a fine bobbin-lace, in which the design is made with the same thread as the ground and woven at the same time. Torchon lace is a coarse bobbin-lace made by the peasants. Limerick lace, made in Ireland, is embroidery on fine net. Filet lace is embroidery on square-meshed net, usually in designs of animals, human beings and sprigs or vines of a quaint, square appearance.

LACE-MAKING IN AMERICA.

In America, both in New York and Chicago, the social settlements have taken up lace-making, and are selling lace-work. The great trouble with lace-making in the last forty or fifty years has been that the agents who bought and sold the laces got all the money. But as, in various ways, it is now possible for lace-makers to sell their work directly to the people who can pay them what it is worth, this lovely art is not likely to be altogether lost to the world.

NOTHING LIKE HAND-WORK AFTER ALL.

The number of stitches used in lace-making and mending is very great, and few lace-workers know even half of them. Sometimes threads will be run across a space so as to form a spider-web network, with a tiny rosette in the center; the needle and thread form sprigs of leaves, vines, roses, letters,—anything, in fact. The edge called a picot is sometimes made by a sort of buttonhole stitch, or a thread may be buttonholed its whole length, with little knots here and there. Most of this work, which used to be done with the needle, is, in the factories, done by weaving, and there is just the difference between machine-lace and real lace that there is between machine-work and hand-work in sewing. If you look at cheap machine-made buttonholes, for instance, you will find that there are corners that are rough or not finished, or a thread left hanging; and it is so in machine-lace. Moreover, another great difference is that machine-lace is nearly always made of cotton thread. The stiffness in cheap laces is due to the fact that they are starched and pressed, to make the pattern show clearly and give body to the lace. Real lace of the same pattern, spread on a cushion, would show the beauty of the pattern without any such aid. But of course, when a real lace collar costs from $15 to $50, according to its size, pattern, and fineness of work, and the imitation lace costs only a tenth as much, most people buy imitation lace. Well-finished machine-made lace, with a good design, is better than a badly made piece of real lace of poor design; but most of the real lace is superior because it is made by people who have done such work all their lives, and the designs are good because they are old, old designs which were made in the first place by artists.

CHAPTER V.

Velvet.

A SOFT ART LEARNED BY MEN OF WAR.

VELVET was first made on hand looms, like silk, and it is supposed that India was its home, and that, when the Greeks and Romans invaded the East, they brought back, as part of their spoils, thick webs of velvet, probably a royal crimson. Velvet was certainly used in Rome for hangings in palaces and temples long before the Romans had any idea how it was made. Their name for it comes from the Latin word *villosus,* meaning "shaggy hair," and, when we speak of the "pile" of velvet, we mean the thick, fine, fur-like nap that covers one side.

HOW VELVET MINISTERED TO RELIGION.

As early as the fourteenth century, velvet was much used in churches, as it had been in the Roman temples, especially in France and Italy. There is a record of one splendid piece of blue velvet, embroidered with gold fleur-de-lis, belonging to the sacred robes in a French church. The altar-cloth was usually of crimson velvet, though black was used upon certain occasions. There is nothing like fine velvet for showing off the beautiful lace which is among the chief treasures of nearly all European churches.

VELVET AND VANITY.

Velvet caps seen in many costumes of the Middle Ages, were quite generally worn by noblemen; and as velvet-weaving became more general in France and Italy, velvet cloaks for men, and even velvet gowns for women, began to appear. But velvet was always more costly than silk, because of the skill needed to weave it well, so that it has not been commonly worn until quite recent times.

FRANCE THE MODERN HOME OF FINE VELVET.

The finest velvets are made in Lyons, though Genoa is nearly as famous for this beautiful cloth. When the silk manufacturers of Lyons brought their goods to the great world's fairs in 1850-67, it seemed almost impossible that a loom could do such wonderful work as was there displayed. Some looms weave velvets with patterns of flowers in natural colors, and a great many experiments have been tried to see if a velvet cannot be made with a nap on both sides, of different colors—the nap on the right side being made of the warp, like any velvet, while that on the wrong side is made of the weft. But, so far, these experiments have not been very successful, because it would need almost a superhuman weaver to do such work.

VELVET AND THE CORONATION.

There are still, in England, hand looms for the weaving of velvet, though only a few of the weavers are left; the coronation velvets for English kings are woven on these looms. The probable reason for the scarcity of weavers is not that the hand loom does so much finer work than the great looms of France and Germany, where most velvets are woven, but because England is not a velvet-making country. At Manchester, some kinds of velveteen, plush, velvet, and velvet ribbon are made, but the best velvet-weavers in England are the old workers on the hand-loom;

and it was felt by King George and Queen Mary that all the robes used for their coronation ought to be made in England.

A BIT OF GERMAN HISTORY.

But most of the velvets sold in this country are imported from Germany, and how they came to be made is a part of history. When the Huguenots were driven out of France by Louis XIV, they took with them most of the silk- and velvet-weaving business of that kingdom. A colony of them went to London and set up their looms at the Spitalfields, while other colonies landed in Germany and started the business there. Two German towns, Elberfeld and Krefeld, do a good share of the velvet-weaving of the world, and they are not large cities, either, as manufacturing cities go. Krefeld has about one hundred thousand people, and one hundred and twenty factories, besides nearly fifty silk-dyeing houses. The German government helps these factories along by courses in designing, chemistry, and other branches, offered by the Royal Textile College at Düsseldorf; and a good many velvets, such as moquettes, panne velvets, Utrecht velvets, and other velvet and near-velvet goods once made only in France, Germany, or Italy, are now manufactured with great success in Germany.

HOW VELVET GETS ITS FUR.

The furry nap of velvet is what makes its weaving especially difficult. This nap is formed by throwing the threads of the silk warp over an extra wire called the "pile-wire," which makes millions of little silk loops standing upright and close together. If the weaving is done so exactly and skilfully that all the loops are perfectly even and woven closely without a break anywhere, the velvet will show a smooth, soft surface when the loops have been sheared. The finer the velvet, the closer and smoother will be the nap, until, in the finest velvets, it resembles the petal of a flower, or the bloom on a peach.

In ''uncut'' or ''unclipped'' velvet, the loops are not cut; this is sometimes called ''terry,'' from the old Gothic word *tairan,* ''to draw,'' and is used for furniture. In ''raised'' or ''Genoese'' velvet first made in Genoa, the pile is of different lengths and forms a pattern; sometimes there is a pattern in velvet on a satin ground. Utrecht velvet is woven of cotton, mohair, wool, or a mixture of these, instead of being all silk, like the true velvets. Velveteen is a cotton velvet that was first made in England and is much used there for gamekeepers' coats and other garments that have to stand hard usage. The rough surface is very well adapted to out-of-door wear in a misty country like England, because the moisture is caught by the pile of the goods and does not soak through; and of course, being of cotton, it is much cheaper than silk velvet.

A GROUP OF INTERESTING VELVET-FACTS.

A silk warp velvet of the best quality is as nearly indestructible as anything made of silk can be. You may cut it into tiny pieces, and it will hardly ravel, any more than if it were a bit of kid; it can be wet and dried again, and, if crushed, it becomes, by steaming, almost or quite as good as new. This is because, in order to be of prime quality, a velvet must be woven more closely and firmly than almost any other sort of woven fabric, so that the nap will stand up straight from the cloth without the tiniest break between the threads.

In the velvet-trade we hear of velvet of from two to six pile quality; this refers to the number of threads in a given space. The velvet usually seen is three-pile, and, in Spain, the word which means this, *terciopelo,* is used for velvet in general.

Velvet ribbon is woven in lengths of about eighteen yards, and this is the only kind of velvet which American silk-mills produce. A cheaper velvet ribbon is made by weaving the cheap cotton velvet in the piece, covering the back with a little gum to make it stiff, and then cutting the velvet in strips of the desired length. The velvet ribbons you see in some very cheap stores are made in this way. But true velvet ribbons, like other ribbons, are woven on special looms of just the right width, and have a little silk selvage on each edge, with a satin-like finish on the wrong side.

VELVET, VELVET EVERYWHERE.

It seems hardly possible that velvet could be used in as many ways as we find that it is today, and the most curious thing about it is that most of these ways were quite unknown, or at least uncommon, even so late as fifty years ago. Velvet is now used for the binding of skirts, the facing of coat-collars, and the trimming of women's hats; numberless kinds of artificial flowers are also formed of it, the cheapest velvets, stiffened with gum on the back, being usually taken for this purpose. We have velvet-covered buttons, velvet shoes, hand-bags, and belts. In household furniture, we find velvet used for cushions, carpets, curtains, chair-coverings, and even picture-frames and book-covers.

PLUSH AND OTHER NEAR VELVETS.

Linked with the velvet business is the manufacture of various other fabrics which have a nap, such as plush, which has a long, shaggy pile; astrachan, which has a curled pile imitating astrachan fur; and beaver which resembles the felt once made from beaver fur. One reason for the great increase in the sale of cheap velvets and plushes is that, until within the last hundred years, velvet was so costly that most people considered a set of velvet furniture entirely out of reach.

This is how plush and Utrecht velvet found a ready use, when they first came into fashion, on steamboats and railways. The idea of the men who furnished cars, and the saloons of boats, was to make them appear luxurious. But today we are beginning to see that a cheap velvet which catches dust will always look as cheap as it is, and, like all shams, is not in the least beautiful even when it is new. So we find the shoddy kinds disappearing from public places and being replaced by hangings and furnishings which are in better taste.

THE FINENESS OF FINE VELVET.

The fine velvets were never so beautiful as they now are. One of these finer velvets, called mirror velvet, is woven in silk of more than one shade, so that its surface changes, with the light, into many lovely tints. There are beautiful stamped velvets also, and then there is panne velvet, which acquires its soft satiny surface by the pressing of the nap after its weaving. The marvelous skill of dyers and weavers have contrived to make fine velvets more cheaply than they were ever made before.

CHAPTER VI.

The Cotton Industry.

HOW THE VEGETABLE LAMB CAME TO EUROPE.

MANY centuries ago, before it was suspected that the world was round, European adventurers traveled into the far East and returned with strange tales of what they had seen and heard in the countries they had visited. One of these stories was of a curious tree which they called the vegetable lamb, because live lambs with beautiful white fleece burst from its pods and hung bleating from their stems. When the wind blew and agitated the limbs the lambs reached down and nibbled at the grass. One traveler, Sir John Mandeville, even declared that he had eaten mutton grown on one of these trees and found it delightful to the taste.

But by the time Columbus sailed to discover a sea passage to India, the people of Europe knew more definitely that the Hindoos made their turbans of a fine wool which grew on trees, or bushes, so when Columbus returned with specimens of the cotton plant and coarse cloths woven from its seed fluff by the natives of the land he had visited, the Spaniards had one more strong reason for believing he had been to India.

Later, when Cortez invaded Mexico, Montezuma gave him some cotton gowns, and among many valuable and rare presents that Cortez sent his sovereign was a cotton handkerchief. So it is evident that cotton was spun and woven in this country before Columbus came.

But it was from India that Europe first imported cotton fabrics. There are records of cotton being planted in Virginia as early as 1607, but, for many years, it was regarded merely as a pretty garden plant.

In those days, only the rich could afford cotton garments; poor people dressed in linen and pure wool, though of so coarse a texture that we would wonder now what good they were to them. Nobody suspected then how the expensive cotton cloth was later to become the clothing of the world's great masses. No other plant is now so universally useful to mankind as the cotton plant—not even wheat, for over half the world still lives on rice.

A ROMANCE AND A TRAGEDY.

The story of this great economic change is one of the romances of modern times and the tragedy of

United States history. Were it not for the humble cotton plant, Abraham Lincoln might not now be an illustrious name and Gettysburg would never have been fought. But the curtain rises on this exciting drama, in which a plant plays the leading part, before the days of the Revolution.

There are two principal reasons why cotton-growing was not encouraged in the American colonies in those early days, though the little that was grown was far superior to Indian cotton, and the climate was especially suitable.

First, the cotton weavers in England could not weave cotton so well or so cheaply as the weavers of India, where the industry was nearly three thousand years old, and where labor cost a fourth as much as in England and perhaps a tenth as much as in the colonies. And, second, it took one day's labor for one man to clean the seeds away from the fluff. So it was infinitely more profitable for the southern planters to raise other crops—tobacco in Virginia, rice in South Carolina, and indigo in Georgia, for all of which there was a strong demand in England.

Then came the Revolution. At once the clothing supply of the colonists was cut off, for the English linen and woolen industries had been sending them all the cloth they needed. During the war, the women spun and wove the famous homespun. Because of the scarcity of wool and linen, the women mixed a good deal of cotton into their weaving. That stimulated the southern planters to experiment in cotton culture. Also, they had suddenly lost the market for their tobacco, rice and indigo.

After the war, looms were set up for weaving woolen, linen, cotton, or mixed fabrics. And just at that time happened another event which further encouraged cotton-growing.

Some of the colonists who remained loyal to England had fled to the West Indies. After the war was over they began returning, and a few brought with them the seeds of a species of cotton grown exclusively in the West Indies. They planted it, and, at the very first crop produced a long, silky white fluff which could be separated from the seed by passing it between two rollers. This was the famous Sea-Island cotton, so-called because it grows well only on the islands or along the sea coast. To this day, this species remains unsurpassed, nor does it grow so well elsewhere as along the Atlantic coast of the Southern States. When the qualities of Sea-Island cotton became known, thousands of Southern planters began planting it, and not only supplied the American looms but exported some to England. There it brought as high as $2 a pound, though common cotton was worth only from 20c to 70c a pound. But this slight beginning was no indication of what was to come a few years later. The extent of it may be judged from an incident which occurred in 1784.

A British man-of-war overhauled a schooner, which was supposed to be English, for the purpose of impressing seamen. The captain of the schooner protested, declaring that he, his crew, and his ship were American. The British captain demanded to see his papers. He observed from them that the schooner carried eight bags—about two thousand pounds—of cotton.

"Where did you ship that cotton?" demanded the naval officer.

"In Charleston; it's American cotton."

"American cotton! So much cotton isn't raised in the United States. You come from the West Indies."

Whereupon the schooner was seized and brought into port, the captain being suspected of piracy.

The culture of Sea-Island cotton was extended, but soon it reached its geographical limits. Producers had tried transplanting it to the inland plantations, but it refused to develop without the moisture of the sea breezes. The cotton which would grow inland contained a tenacious, green seed to which the fluff clung like tar-weed. It took one person a whole day to clean one pound, and the roller gin, which cleaned Sea-Island fairly well, could do nothing with it. Consequently not much cotton was raised inland.

But now, toward the close of the century, we come to the great event of United States history, compared to which all the battles rolled into one would be only an incident. That was the invention of the cotton gin by Eli Whitney. Other inventions may have been equally beneficial, but the gin, coming when it did, has brought about more far-reaching results than any other single invention—results that have affected every nation and every people, civilized or uncivilized, on the face of the globe.

HOW A COLLEGE STUDENT CREATED AN INDUSTRIAL REVOLUTION.

The invention of steam power, first applied to the loom in 1785, made it possible for British textile workers to spin and weave cotton cheaper than the hand-weavers of India could do it; so Great Britain began importing the raw cotton. But the power looms soon swallowed all the raw cotton that India could send. Even the teeming millions of the East could not clean the fluff from the seeds as fast as English spindles could spin and English looms could weave. The American planters sent to England all the Sea-Island cotton they could raise, but, even with the increased demand, it still did not pay to clean the green seeded cotton of the interior.

About this time, in 1792, Eli Whitney, a Massachusetts boy, who had just been graduated from Yale, started south to teach school in South Carolina. On the way he met Mrs. Greene, the widow of Major-General Nathaniel Greene, the famous Revolutionary hero, and she invited him to spend a few days at her home near Savannah, Georgia. Whitney was an inexperienced Northern boy; he had never seen a cotton field and he would hardly have known a cotton plant from a banana tree. But, while visiting Mrs. Greene, he heard her neighbors discussing the still unsolved problem of cleaning the green seed-cotton. He heard one of them speculating over the fortune that awaited the man who would invent a machine that could do the work.

Whitney, who had an aptitude for mechanics, brought the subject up again, in a conversation with Phineas Miller, the superintendent of Mrs. Greene's estate. Mr. Miller showed him samples of the unseeded cotton and explained the difficulty. The result of their talk was that young Whitney began experimenting. Within ten days he produced a model of a gin.

It consisted of a number of circular saws fixed on a cylinder. Attached to the cylinder was a wire cage, whose bars were so close together that there was just space for the saws to enter between. The cage was jammed full of unseeded cotton. The cylinder turned close to the side of the cage, so that a segment of the saws entered and revolved within the cage. As they turned, the sharp teeth of the saws caught the fluffy lint and pulled it through the bars, leaving the seeds behind, as they were too large to pass.

Mr. Miller was now very much excited. But the machine still failed to work; the lint came through on the teeth of the saws very well, but after a few dozen revolutions, they clogged up and stopped.

They were puzzling over this difficulty in Mrs. Greene's kitchen, one day, when she came in and watched them. In her hand she carried a small hearth-brush.

"Why don't you use this?" she said, laughingly, and she made several dabs at the saws with her brush. Some of the lint came off and clung to the brush.

The suggestion was offered in jest, but it solved the difficulty. Mrs. Greene was destined to become a far greater revolutionist than her husband. Whitney added to his machine another roller, studded with stiff hog bristles. This revolved against the saws, in an opposite direction, sweeping off the particles of cotton as they were ginned.

There have been many improvements in the cotton gin since then, but it still operates on the same principle. In April of 1793, Whitney and Miller put their first gin to work. Mr. Miller, who meanwhile had married Mrs. Greene, had the necessary capital and they went into partnership. Unfortunately, they conceived the plan of creating a monopoly of ginning, instead of patenting the machine and selling it at a fair price to the planters.

The news of the invention stirred the whole South. But enthusiasm turned to anger at the attempted monopoly. One night a determined mob broke into one of the ginneries and carried off the machine. Within a few months the simple device had been duplicated in many parts of the country. Years later, some of the cotton-growing States made appropriations to reward Whitney for his invention, but it was hardly enough to reimburse him for his expenses in fighting the infringements of his belated patent. He lived and died a poor man.

Most of the Southern planters were cultured gentlemen of education, and they were not slow in realizing the significance of the gin. It was an inexpensive machine, as used at first; one negro could turn it easily and do the work of fifty men. Later, with the application of steam, its capacity was many times increased. But, even from the very beginning, it made the cultivation of the green seed-cotton profitable, opening up all the waste lands of the interior. Hemp, rice, tobacco, flax, and barley were abandoned. In one year, hundreds of grist mills stood idle, left to fall into ruins. South Carolina, which, in 1792, had exported one hundred thousand bushels of corn, soon had to import it for domestic use.

In 1793, the year in which the gin was invented, the United States had exported a bare half million pounds of cotton, most of it the Sea-Island. Seven years later, sixteen million pounds were sent to England alone, and, after another five years, half of England's whole tremendous supply of raw cotton came from the Southern States. By 1858, England was getting four-fifths of her cotton from the South.

These were the immediate and visible results. But other results, not so obvious, were at work deep down in the vitals of the nation.

NEGRO SLAVERY, AND A MACHINE THAT WOULD HAVE ABOLISHED IT WITHOUT WAR.

To understand the tragedy of the cotton gin we must go back again to colonial times. After England had granted huge tracts of land to wealthy gentlemen in Virginia, she found it convenient to sell them her convicts for cultivating the tobacco plantations. Long after, when this custom was abandoned, the planters suffered from a scarcity of labor. But they found some relief in following the example of the sugar planters in the West Indies; they imported African negroes as slaves.

Yet, in spite of the fact that the climate permitted field work the year round, slavery did not flourish in the South in those early days. Washington, Jefferson, Madison, Patrick Henry and Richard Henry Lee, as well as many other prominent Southerners, were opposed to it in principle and favored its gradual abolition.

Then came the cotton gin, which meant that as much cotton as it was possible to raise could be sold at a high price. There was now only one limitation to the production of cotton, and that was labor. Every pound of cotton had to be picked by hand, a form of labor to which the negro was especially adapted. Naturally, after that the value of an able-bodied slave doubled; in 1792 he had averaged only $200. Slavery as an institution took new root. Men who opposed it on moral grounds upheld it as an economic necessity. It grew to be a common belief that the world's supply of cotton depended on negro slavery.

So, while the cotton looms cried "More! More!" cotton-growing extended as far north as the climate would permit, then westward into the Mississippi Valley and down toward Texas. Wherever the planters went, the slaves went with them. The raising of slaves for the cotton fields became an industry.

The war with Mexico was the first blood shed by the cotton gin. It came because of economic conditions; American planters needed the excellent cotton lands in Texas. At this time a husky slave would bring as much as $1000.

And so drew on the rivalry between the two systems of labor; the slave system in the South and the wage system in the North. Each represented a different type of industry and each instinctively felt that the two could not prosper together. The slaveholders tried to extend their system into the West; the Northern people tried to restrict them. And so came about the split and the War of Secession. Only one thing could have saved us from the calamity—another invention that should counteract the influence of the gin. Had a machine been devised to take the place of the negro slaves in harvesting the cotton crop, as the reaper harvests the grain crops, slavery would have ceased to exist. Slaves would have been such a drug on the market that they would not have been worth their own keep. Planters who owned more than enough slaves to perform household duties would have found no use for them. The Southerners themselves would have put an end to slavery, and so there would have been no cause for difference with the North. But the machine that could have saved the United States from four years of bloodshed and misery, was not to come for another fifty years.

A MACHINE THAT FORECASTS A STILL MORE TREMENDOUS REVOLUTION.

When the Civil War broke out, England, which then manufactured practically all the cotton goods of Europe and much of America, was getting four-fifths of her raw cotton from the Southern States—almost three million bales. The war suddenly cut short that supply, and about a quarter of a million of English factory workers were thrown out of employment, causing as widely extended misery as was suffered in the United States, where the war was being fought. Of course, England began increasing her imports of cotton from India and it was almost universally believed that the cotton-growing industry of the Southern States was ruined forever; that it would die with the abolition of slavery. It was reasonable to believe that American free labor could never compete with the cheap labor of India.

But this belief proved absolutely unfounded. In spite of the stimulus the Civil War gave the cotton industry of India, within a few years after Lee surrendered the United States was producing as much cotton as ever, and shipping as much to England as before. For it is the superior quality of American cotton that enables it to control the market. Just before the war the annual production was about five million bales; now it is about twelve million.

In fact, the cotton industry has done better without slavery. Under slavery, a small planter could not compete with the large planter, because he had not the capital to invest in slaves. After the war, he was on an equal plane with the rich planter, for then both had to hire their labor at the same price. Also, many of the ex-slaves obtained small pieces of land for themselves and, being their own masters with an interest in their work, they produced more cotton than when driven to their work by the overseer. So, while the big planters did suffer, the South as a whole gained.

Yet the supply of cotton continued to be limited by the supply of labor. Commercial experts, even after the war, would estimate the quantity of the coming cotton crop by the number of pickers available. When the picking began, every man, woman and child would be put to work. Even vagrants were arrested and set to picking cotton, and the convicts in the prison were marched out into the fields under guard. For, no matter how many pickers there were, the looms continued their cry of ''More! More!''

All this has been true until now. Another economic revolution is, however, pending in the South, possibly as tremendous, if not as tragic, let us hope, as the revolution precipitated by the gin. The long needed cotton harvester has appeared and begun work.

Twenty years ago a Scotch mechanic, Angus Campbell, made a vacation trip to Texas. Like Whitney, he knew little about cotton, but he saw the need of a machine to do the work of the negro cotton pickers. So he began devising a model.

The task before him, however, was not so simple as Whitney's. The cotton grows in the seed-pods of a bush whose height varies according to the climatic conditions of the locality or of the season. Nor do the pods all ripen and burst open at the same time. The fluff from each pod must be picked out, leaving behind the pod and the stalk, and the unripe pods must not be touched. The same field must be gone over several times during the picking season, which lasts about three months.

Since that first visit, twenty years ago, Mr. Campbell has experimented continuously, making over fifty-five designs. But, at every trial of his mechanism some defect developed, which could not be corrected until the next season. In 1910, however, success came; the machine worked, picking about six thousand pounds of cotton in one day of ten hours, doing the work of about twenty-five field hands.

The new machine is driven by a thirty-horse-power gasoline engine. Beneath the engine are the picking attachments, from which a pair of canvas bags hang out behind. It moves over the rows of plants, the broad, heavy wheels passing along between the rows without injuring the bushes. Two drums are suspended from the machinery. Upright cylinders, in an endless chain, follow one another around the drums. From these revolving cylinders teeth, or spindles, project, which catch the ripe cotton at an angle, gently tearing it out of the pods. Meanwhile, the large drums also turn, and the cotton is carried back and dropped into the canvas bags. The unripe pods, being closed, present no fluff for the spindles to catch in, so they are passed over uninjured, to be picked at some later time when they ripen and the fluff has burst forth.

Tests which have since been made prove that the cotton picked by the new harvester has in no way been injured; it is quite as good in quality as the hand picked cotton. This much could not be said of the gin when it was first used.

For a beginning, this first demonstration has been remarkable, compared with the first efforts of the grain reaper and other similar inventions, which required years of constant experiment and improvement. Therefore it is safe to predict that the cotton harvester has come to stay.

We can only surmise what the economic results will be. Undoubtedly the small planter, the negro farmer raising a couple of bales of cotton each year, will be at a disadvantage, for he cannot afford this expensive machine. Of course, as is done in the West with the big grain harvesters, the machine will be hired out for service by men who will invest in it for that business, but the planter, who can own his own machine and control it as he needs it, will always have an advantage.

The chief result will be the displacement of human labor. The millions of negroes required each year to pick the cotton crops of the South will be needed no longer. Perhaps they will now begin to flock to the cities, as the farm laborers of the West did after the reaper came into general use. Others will raise garden produce, much of which is now shipped in by many of the cotton-growing districts. At any rate, though there may be temporary suffering, there will always be other work to be done, as long as people demand food, and clothes, and shelter.

Finally, the endless and hitherto unsatisfied demands of the spindles and looms, now numerous in this country as well as in England, will be met in full. There need be no limit to the supply of harvesters. The cotton planters may take up more land, now idle, and sow as much cotton as they please, knowing that, however much they may plant, it can always be harvested.

CHAPTER VII.

Spinning and Weaving Machinery.

AN ANCIENT AND HONORABLE CRAFT.

SO ancient is the craft of the weaver that we have no historical records of any time in which it was unknown. We cannot even guess, with all our scientific knowledge of prehistoric periods, where and by what people it was invented.

Undoubtedly it was discovered in a great many separate places, for tribes and peoples who presumably never came into contact with each other could spin and weave excellent cloth; the Aztecs of Mexico, the Peruvians of South America, the Hindoos of India, and the Druids of ancient Britain.

The attempt to gather the tufts of wool caught in thorny bushes from passing sheep and twisting it in so doing, may easily have suggested spinning to a thoughtful shepherd. The necessity of interlacing boughs and saplings in building huts could equally as well have led to weaving, first rushes and vines, then threads.

Spinning, until recently, was always a simple operation. In the Philippines today we may see these brown brothers spinning by exactly the same means as were employed by the ancient Egyptians six thousand years ago, as illustrated on such walls of their buildings as are still standing. The wool, or the cotton, is tied loosely to a short stick, which is held under the left arm. With the left hand the spinster pulls out a pinch of the wool and begins twisting it with the right hand. When a few feet of thread has been made, the end is tied to a sort of long top, which is suspended in mid air and twirled by the right hand. As it spins around it continues twisting the thread, while the spinster keeps pulling it out of the bunch of raw material tied to the end of the stick, which is called the distaff. The twirling top is called the spindle, around which the thread is wound when it becomes too long.

Almost everybody is familiar with the primitive loom; in many parts of America it is still used by the farmers in making rag carpets. The hand loom was perfected within historic times, for many of the ancients wove by the darning process. They stretched out the threads which we call the warp, then passed the cross threads back and forth with a needle, lifting each alternate thread of the warp just as a stocking is darned.

The first improvement on the primitive distaff and spindle came some time in the twelfth century in the form of the picturesque old spinning wheel, whereby the spindle was turned by a treadle. Of course, this went much faster, but the speed that was to create a revolution in the textile industry was not yet attained.

A MACHINE WITH A WOMAN'S NAME.

The next great improvement came about the year 1764, when an English weaver, James Hargreaves, invented a machine with which ten separate threads could be spun at once. Hargreaves named the machine a ''spinning-jenny'' after his wife, whose name was Jenny. It was impossible, of course, for the operator to regulate ten different rovings at the same time, so the rovings were run between parallel bars which could be closed down when the thread was to be stretched and wound on the spindles.

A MACHINE NAMED AFTER AN ANIMAL.

Hargreaves' spinning-jenny was soon superseded by improvements made by Richard Arkwright and Samuel Crompton. Crompton invented the mule-jenny, on which the spindles were attached to a moving frame which shot out on wheels when the thread needed pulling, the spindles twisting it meanwhile. As the spindle frame moved in again, the threads were wound on the spindles. The various forms of modern spinning machinery are made on the same principle. Now one girl operator controls hundreds of whirling spindles, having only to tie the threads when they break.

MANY MACHINES OF MANY NAMES.

As with every new invention in a great industry, its increased capacity is useless unless the other processes keep up with it. Spinning-jennies might turn out millions of miles of thread, but unless that thread could be used as fast as it was made, the usefulness of the spinning-jenny was closely limited. That brought about a new series of inventions in weaving machinery. Perhaps it would be more correct to say that the inventions in both departments reacted on each other, for, even before the spinning-jenny had been perfected, the flying shuttle had hastened the process of weaving. In fact, spinning and weaving have kept about an even pace with each other. Above all, it was the cotton gin, invented by Eli Whitney, which suddenly threw mountains of cheap cotton on the market, that accelerated invention in the whole textile industry.

It is in the application of power, rather than in any radical change in its mechanism, that the modern loom differs from the old fashioned hand-loom. Moreover, the machine has never been able to compete in excellence with hand power. "Hand woven" is still a stamp which denotes superior quality, and, in certain lines of artistic weaving, the power loom will never displace the hand loom. But the mass of the people look more to the wear in their clothing than to the art in making it.

In the hand loom the weaver throws the shuttle, holding the weft, back and forth between the changing rows of the warp. By machinery the shuttle is shot from side to side at the rate of from one hundred and eighty to two hundred and fifty strokes a minute. When the thread carried by the shuttle breaks, the machine stops automatically, and the girl operator pieces the ends together.

There are also various forms of special looms for weaving designs into the cloth. The first of these was invented by Jacquard, a Frenchman, in the last decade of the eighteenth century. Before his invention, figured cloth could be made only by a slow and laborious process. Briefly, the invention may be described as employing the principle of stencil lettering. The designs are cut out on stiff paper, then passed over the warp. Needles pass through the openings in the paper and lift the warp, allowing the weft, by passing over them, to form the designs.

CHAPTER VIII.

Thread Manufacture.

FROM EGYPTIAN DISTAFF TO INDIAN WHEEL.

IN all very old pictures of spinning, you will see the spinner, not with a wheel but with a distaff; and this was the way of spinning everything—cotton, linen, and wool—until the time of Henry VIII in England. About that time the first spinning-wheels were brought from India, where they had been in use for many centuries, but, instead of having the quaint, lopsided frames that we find in our garrets, they were square-framed, like a grindstone. The cotton threads spun by hand were so irregular that they could not be used for both warp and woof in weaving, but only for the woof, the warp being made of linen threads. The wheel was a great improvement over the distaff, because it turned the spindle faster and more evenly than it could be turned by hand.

FROM ONE WHEEL TO MANY WHEELS.

But only one thread could possibly be spun by one worker on a wheel; and so, when James Hargreaves, about 1764, devised a frame called a spinning-jenny, in which ten spindles turned at once, it was a long step forward in the art of spinning. Afterward, he made a larger jenny with eighty spindles. The other spinners were greatly stirred up over this machine, and, to save it from being smashed by a mob, he had to take it to Nottingham, where he built a small mill and started it going. Soon afterward, Richard Arkwright came to the same place with his throstle machine, a roller-spinning device, and together these two men revolutionized the spinning industry in England. In 1779, Samuel Crompton, of Bolton, invented a machine that combined both devices. In this machine the spindles were set in a carriage, or ''mule,'' running back and forth about five feet. As this mule shot forward, it drew out the cotton, twisting it into thread at the same time; running back it wound the thread on the spindles. The earliest of these machines were made with only twenty or thirty spindles, but later they carried over two thousand spindles each, controlled by one spinner.

What is called the ''fly-frame'' came into use in 1817, and, for cotton, has taken the place of Arkwright's machine. A great many other improvements have also been made, both in spinning and weaving.

SPINNING YARNS AND THREAD.

The finest spinning will give about three hundred hanks of thread to the pound, but the commoner kinds of thread run from about ten to forty hanks to the pound. After the spinning, the finer yarns are singed by a gas flame; they are then passed over a brush, and run through a hole in a piece of brass just large enough for the yarn. The yarns are made up into bales weighing five or ten pounds; they are then ready either for weaving or for being formed into thread.

In old times, sewing-thread was always wound in hanks, and you may yet see little old-fashioned sewing-cases with stitched pockets for the thread. But, for more than half a century, all our sewing-thread has been wound on spools. In England, they call them ''reels,'' and customers ask for a ''reel of thread;'' Americans call for a ''spool of cotton.''

GIVING A TWIST TO IT.

If you untwist any kind of thread, you will see that it is composed of two or more finer threads rolled into one. But why should thread be twisted? To make it stronger, of course. Another question: Why is it stronger when twisted, than when it is only double? That will take longer to answer.

Examine several different kinds of thread—say, embroidery-cotton, sewing-cotton, buttonhole twist, darning-cotton. You will find that, while the sewing-cotton is closely twisted, the others are twisted scarcely at all. Put two threads of the embroidery-cotton side by side and you will probably find that they are a little uneven, a weak place occurring here and there. Twist them together and you will get a more perfect whole, as the weak places in one thread are re-enforced by the stronger parts of another. But, in embroidery, the work must merely be smooth, with the thread lying snugly around the corners of the design; strength is not needed. If you try doing a bit of fine embroidery with thread as coarse as the cotton, you will have a very rough and knotty piece of work; the twisted threads will not lie close in a satiny surface. On the other hand, for sewing a seam or making a button-hole, we need a firm thread, composed of two or more closely twisted yarns.

Darning-cotton is loose and soft, like embroidery-cotton, and for the same reason—because it is to be woven smoothly together, and the weaving will make it strong. When a good seamstress has to darn a tablecloth, she does not use ordinary thread. She takes a raveling of the cloth, or fine darning-cotton as nearly like the thread of the weaving as she can find.

Thread is usually treated to a bath of gum to give it firmness, and sometimes it is made of mercerized cotton (see Silk), which gives it a beautiful, silky appearance. Linen thread costs more than cotton, and is used only for work where very strong thread is needed; you can hardly break linen thread with the fingers. It is also used for knitting or crocheting linen lace, and for some other sorts of fancy work; but most of the thread in the average work-box is cotton.

The numbers of thread range from about six, the coarsest, through the even numbers up to twenty, and then we find thirty, forty, and so on, up to two hundred or more.

THE STRING TRIBE.

There is a kind of spinning which furnishes employment to a great many hundreds of people but is hardly ever thought of, and that is the spinning of rope, twine and string. It is done on special machines, fitted for strong, coarse work as compared with thread machines; but the whole tribe of strings—fishline, ratline, tow-string, twine, jute, hemp—are twisted just as fine thread is twisted.

AN INTERESTING THREAD INCIDENT.

It is hard to realize that any human being can be deft enough, and have quick enough eyes, to use the finest and most delicate thread that is spun, but it is all used. Laura Bridgman, who was blind, deaf and dumb, could, nevertheless, with her marvelously sensitive fingers, knit fine lace-collars out of thread almost impossibly fine for a seeing person to use.

CHAPTER IX.

The Sewing Machine.

MEN TRYING TO MAKE WOMAN'S WORK EASIER.

MORE than a hundred and fifty years ago the busy brains of inventors were already at work on the idea of the sewing-machine. Sewing seems such a simple business when done by hand, that it is astonishing to find how hard it is to devise a machine that will do all that the hand does so easily. The first inventors tried to imitate hand-sewing with a needleful of thread, but the first man to hit on a needle that could possibly be used in a machine was Charles Weisenthal, who got a patent in England, in 1755, for a needle pointed at both ends and with an eye in the middle. It would pass either way through the cloth without being turned around. The first object of the inventor, of course, was to get rid of as many as possible of the motions the hand makes, and so simplify the machine.

THE FIRST MAN WHO BEGAN TO SUCCEED.

In 1770, Robert Alsop invented a machine for embroidering in a loom, and, in 1790, Thomas Saint devised a machine something like the modern sewing-machine, but with a forked needle. It might have been used for sewing leather, but woven stuff would have caught on the forks of the needle.

THE MAN WHO FIRST SUCCEEDED.

It was not until 1846 that Elias Howe patented the first sewing-machine that would really sew. It had a grooved, curved needle with an eye in the point, which penetrated the cloth and formed a loop through which a shuttle passed another thread. The needle did not move up and down like a modern machine-needle, but back and forth, the cloth being held in front of it by pins projecting from a "baster-plate" moved by a toothed wheel. When the end of the plate was reached, the cloth was taken off and put in place again. The nimble seamstresses of Howe's time, looking at his rude little machine, must have smiled and said that they could sew as fast as that by hand.

OTHERS WHO SUCCEEDED TOO.

The next improvement was to make the needle move up and down and "feed" the fabric along under it, and when this was done it really began to look as if Howe had a great invention. Then Isaac Singer of New York, a merchant with plenty of money, became interested and went to work at the problem, as did other inventors, and presently the "Wilson four-motion feed" was invented. This solved the problem of moving the cloth along without interruption to the work. A saw-toothed steel bar works in a slot in the plate on which the cloth rests, first going forward, carrying the cloth with it, then down, back, and up again, while the needle is poised over the cloth. The "lock-stitch" is formed by the thread passing through the loop of thread which the needle makes, the needle carrying a thread from a spool above, and the shuttle, or bobbin, another thread below. So machine-sewing by lock-stitch differs from hand-sewing, because hand-sewing is done with only one thread, while, on the machine, two threads meet from the upper and under side of the seam, and "lock" together.

ANOTHER CASE OF WHERE AMERICA GOT IN FIRST.

It usually seems, when a great invention is made known to the world, as if the idea must have come to several men at the same time, for almost always more than one man claims to be the originator. In 1830, Bartholemy Thimounier, a Frenchman, invented a sewing-machine which was actually used by the French government. Fifty of these machines were in use in 1841, making clothes for the army; but a mob, seeing in these improvements loss of employment for hand-workers, wrecked the machines. The inventor, in 1851, came over to the United States, to try his luck. By that time, however, Howe's machine, a better one, was on the market.

A GREAT COMBINATION.

One of the most important early improvements was the yielding steel spring that holds the cloth smooth. Until that was devised there was no way of sewing with equal ease whether the seam was thick or thin. Sewing-machine companies sprang up like mushrooms all over New England and New York, as soon as it was really proved that Howe's machine would sew. The first factory for making sewing-machines was built in Bridgeport, Conn. In 1860, there were eighty-eight companies making machines; but, in 1856, all the inventors completed an agreement to "pool their patents"—that is, to let all those in the agreement use all the patents. This, of course, made it possible to combine the special features of all the inventions, and the use of sewing-machines spread much faster than if each had had some few good qualities which the rest lacked.

Today there are only sixty-five companies in the United States, but about thirteen times as much capital is invested in the business, as before the combination was formed, and the number of people employed in making machines has increased from two thousand, five hundred to more than thirteen thousand. In 1900, more than fifty-five thousand machines were made, New Jersey supplying the largest number. In every factory there is an "experimental room" where the inventors can have everything they need to work out improvements in the machines, and improvements are always being made. Often the tools used in building the different parts of a sewing-machine take longer to make, and are more ingeniously constructed, than any part of the machine itself.

THE WONDERS OF THE MODERN MACHINE.

Sewing-machines are now made with a large number of "attachments," or additional parts for some special use. There are attachments for making buttonholes, for hemstitching, embroidering, ruffling, tucking, hemming—in fact, any sewing that needs to be done. It is possible for a skilful dressmaker to make a complete suit without using a needle other than a machine-needle. She does not even baste the pieces, but pins them, and the machine runs so true that the seam is as smooth as if it were one piece. In a collar-factory a woman may earn a comfortable living making buttonholes at a few cents a hundred, the buttonhole being made with one or two motions of its special machine. The modern machine runs much more easily than did the old ones, and with but little noise; and in all great dressmaking establishments and tailor-shops the worker does not supply the power; the machine is run by gas, steam or electricity, generally the latter.

THE BABY OF THEM ALL.

One of the latest improvements is a little hand sewing-machine which can be packed in a trunk and is only a few inches tall. While of course this will not answer for very heavy work, it is a convenient thing to use in traveling, and a little girl can easily do her doll's sewing on such a baby machine.

CHAPTER X.

The History of a **Hat.**

THE ROMAN AND THE LITTLE ROUND HAT.

IF you see a day-laborer going home from work, wearing a round, soft, felt hat with the brim turned up in front, you see very much the sort of hat that the laborer of old Rome wore when he started homeward after doing his day's work on some new aqueduct. The felt hat is a very old invention, and for at least two thousand years it has been made in that basin-like shape.

A GOOD MACHINE WITH A WICKED NAME.

The difference between the hat of ancient history and the hat of today lies in the making. Until about seventy-five years ago, almost all the work of hat-making, whether of straw or felt hats, was done by hand. Now nearly all of it is machine-work.

The first step in making a felt hat is to shear the fur from the skin, and this is done by a set of revolving knives, the sheared skin passing under a table and leaving the fur on top. The fur is then mixed so as to get a fair average quality, and one-eighth the same weight, or less, of fine carded cotton is mingled with it, in a machine called the ''devil.'' Foreign particles are sifted out in the ''blower,'' which is made up of cylinders whirling several thousand times a minute. Then the fur is ready for felting.

FOLLOWING A HAT THROUGH THE MAKING.

It used to be believed that St. Clement invented the making of felt, and November 23, his feast, was the particular holiday of the hatters. But the real patron saint of the hat business, as it is conducted now, was Henry A. Wells, who, in 1846, invented a machine for making felt. It has an upright cone of sheet copper perforated with many little round holes and this cylinder turns slowly above an exhaust fan that makes about four thousand revolutions a minute, and causes a current of air to blow downward through every one of the little holes. Above the cone there is a box with a hole in it, into which the fur is ''fed'' and driven through this hole upon the sides of the cone as it turns, thus forming a perfectly even coating of matted, furry fibres. When this coating is thick enough, the workman wraps cone and all in a wet cloth, puts another cone of metal over it, and places them in a tank of hot water, which makes the felting firmer. Sometimes, instead of this process, jets of hot water, or spray, are thrown on the cone. It is easy to see how hard it would be to do by hand the work which this ingenious machine performs so quickly and so perfectly; and it is only one of dozens of inventions in use in every hat-shop.

The felt cones are then rolled and pressed, and the next step is the "sizing." A pile of several cones is dipped in hot water and rolled in a piece of blanket on a sloping table. A little shellac dissolved in alcohol is generally used in sizing, and this makes the felt firmer and stiffer, and gives it a better finish. If you take a piece of old felt, wet it, and pull it about, you will see how easy it is to shape felt when it is damp.

After the hats are dyed, they are moulded on blocks of the right size and shape. Up to blocking, of course, the hat is just the shape of the brass cone on which it was built. The blocks were formerly of wood, and every hatter had a large collection, just as every shoemaker had a collection of "lasts." Sometimes the hatter carries on the whole work from the beginning, but more often he gets the felt cones from another manufacturer, and only does the moulding and finishing, on which the appearance of the hat mainly depends.

In making a stiff hat, or "derby," the shaping is done by a hydraulic press, which presses the hat down on the block, over a jet of steam. Hand work is more often employed on soft hats, except ironing the crown and brim which must be done by special machines. To iron the crown, the hat is turned around and around against a gas-heated iron, and the brim is ironed in much the same way.

Then comes "pouncing," or the smoothing of the surface of the hat with emery paper. Sometimes this is done by machine and sometimes by hand, the workman having in one hand a pad of pouncing paper, and putting on the pouncing powder and grease with the other. This makes the dull felt smooth, clear, and bright. Then it is put on a block again and pressed into shape with a hot iron. The brim is curled between two small wheels, and this requires a special knack. Sometimes a man will show that he has this knack the day after he goes to work, and he will curl hat-brims all day without making the slightest error. And there are men who work at hat-making twenty years without being able to curl brims.

The trimming and binding are usually done by girls with sewing-machines. Finally, the hat, with a bag of hot sand inside, is rounded by a gas iron, and, if it is to be "telescoped," bits of cardboard are put inside and the final shaping is done over them. There is probably nothing in all a man's wardrobe that is handled so much in making, as a hat.

Great improvements have been made in the dyeing of felt. In Queen Elizabeth's time, a black hat was likely to get so rusty that the owner would smoke it in the pitch-pine smoke of "links" or torches to make it black again! Today hats can be cleaned and dyed so well and cheaply that a fine felt is a good investment.

A CIVIL WAR INCIDENT.

There are about fifteen cap-visor factories in America, most of them in New York. One man has been in this industry for fifty years, and remembers how he and his fellow-workmen sat up nights making visors for soldier-caps, when the Civil War broke out. Most visors are made of some kind of leather, though there is an imitation leather, of bookbinders' board, covered with what is called "moleskin," which can hardly be told from the real. Some visors are also made of cloth, or of waterproofed canvas.

THE HAT IN HISTORY.

The hat has more of a place in history than most other articles of the wardrobe. Away back in the time of King John, the De Courceys were allowed the privilege of wearing their hats before the King, though the last De Courcey who really did it lived in the time of George the Third. The Quakers make a point of keeping their hats on their heads, to show that they do not bow down to earthly dignities, and the Jew always prays with his hat on, even if he is only saying grace at table. The red hat is the symbol of a Cardinal of the Catholic Church.

The stiff derby hat is modeled on the old-fashioned helmet, and, when it first came into style, was a protection, times then being so unsettled that a man might, at any time, need defense from a blow on the head. Since the invention of the various hat-making machines, these hats can be turned out so rapidly and cheaply that they are worn everywhere—even in Japan, where a great many of them were sent when the Japanese first began to buy Western goods.

There was a time when the silk hat, popularly called a ''stovepipe,'' was worn by every man who wanted to appear dignified. Most people will go wide of the mark if you ask them how high one of these hats really is. They look, when perched on a man's head, as if they were much more than seven inches high. The tall white beaver hat which Uncle Sam is always pictured in, was much worn about the time of Harrison's ''Log Cabin'' campaign.

The first silk hat was worn in London in January, 1797, by John Hetherington, a hatter who wanted to advertise the new style. He was followed by such a crowd that they arrested him and put him in jail for making a disturbance in the street. President Lincoln always wore a silk hat, and so did most of the other great men of his day, here and in Europe. But now it is only worn, as a rule, with evening dress or on some formal occasion in the daytime. It is the only kind of hat which can be bought cheaply in the shop where it is made, and, in London, one may often see a very shabbily dressed man with a shining silk hat on his head. Many of these hats, too, are sent to jungle towns. To a savage, a high hat is a sign of great dignity, and when he has one on he feels well dressed.

The green felt hat, so often seen about 1908, was brought into fashion by King Edward, who wore one when shooting in the Tyrol, and had his picture taken in it. The cowboy hat is a descendant of the Spanish "sombrero," and is probably the most useful soldier-hat ever invented, for it keeps off the sun, rain or snow, and can be used either as a pillow or a drinking-cup, if necessary. The "shako" or tall fur hat worn by drum-majors and some foreign troops, comes from the Hungarian fur cap or *csako,* and the idea of putting it on soldiers was to make them look more fierce and imposing. Today, when endurance on long marches is the quality most needed in a soldier, troops all over the world are wearing simpler and lighter head-coverings.

The light pith helmet has come into use in the tropics, and is made from the pith of the spongewood or sola, a swamp-plant with a thick stem and white pith. Sometimes this is used for another kind of hat, which looks like a huge mushroom and is called a sola-topi (or solah-topee). It is usually lined with green silk to soften the glare of the white brim, and is rather like a shade-hat and sun-umbrella combined; but in India, where it is most worn, it is a very useful, if not entirely handsome, article.

The Chinese coolie wears a huge flat hat nearly three feet across, made of straw woven in a sort of basket-work, and lined with paper; and the Japanese peasant wears a hat which looks like a small straw-stack and best of all, sheds the rain.

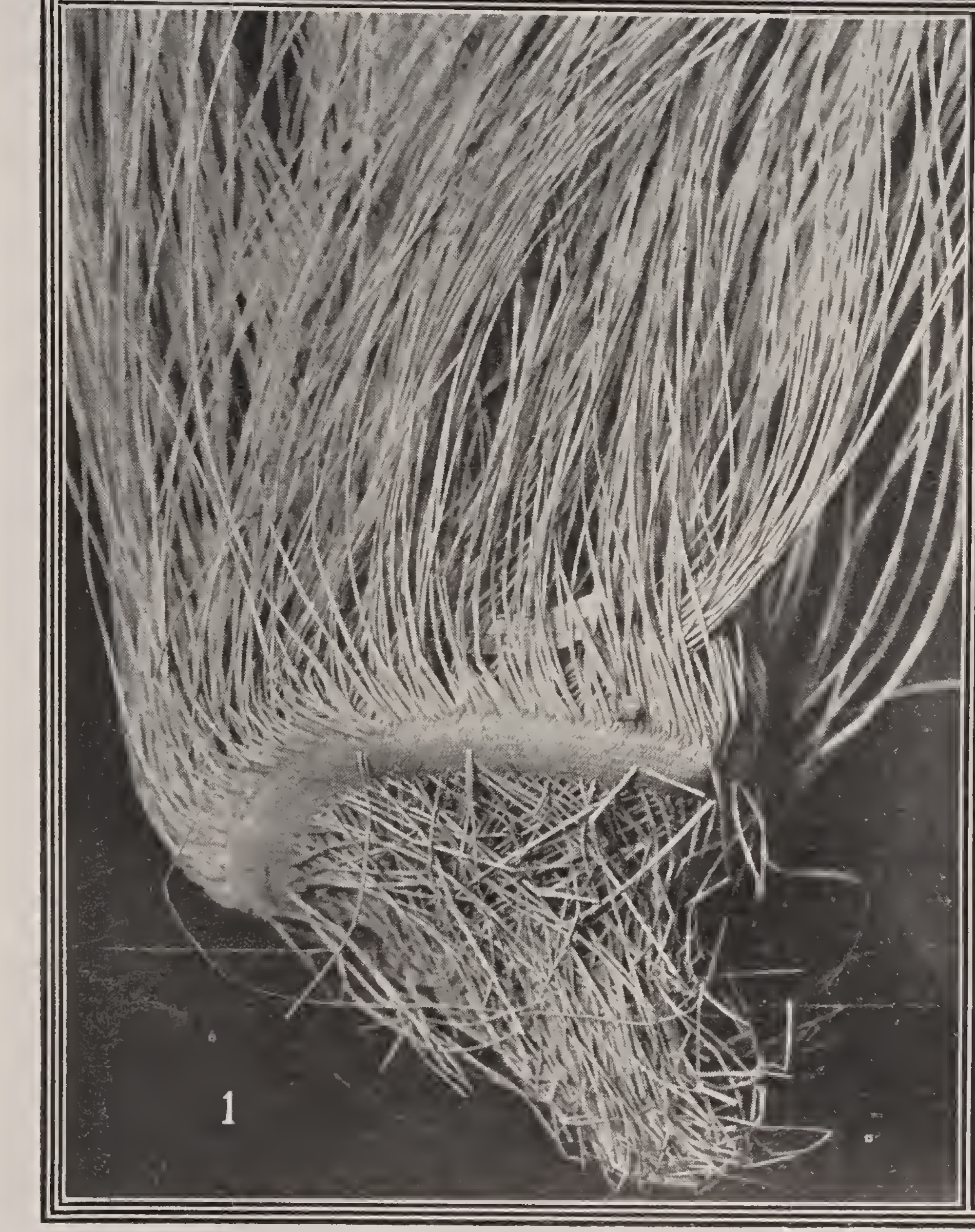
EVOLUTION OF THE COOL STRAW HAT.

Straw hats have been in vogue in tropical countries for a good many centuries. But, in Europe, they did not become very common until about the year 1800, Carbonari, an Italian, began making the wide hat or *fioretto* which we know as the Leghorn hat.

These hats, and other hats of fine straw, are made of wheat straw. The wheat is planted as thickly as possible, so that the stalks, instead of being big and strong, will be spindling and weak, as trees are when they grow too closely in a wood. The grain blooms at the beginning of June, and, when half-developed, it is pulled by hand. If it were left to grow longer the stalks would be brittle. It is collected into little sheaves of about five dozen stalks each and stored in barns; there, during July and August, it is bleached, when the weather is suitable, for about a week out of doors. Afterwards it is bleached again with sulphur, and the straws are sorted by a *sistola,* or series of sieves.

Straw braiding is generally done by women and girls at home, who make a little extra money in this way. Most of the straw used in American hat factories comes from Italy, China, or Japan. In an Italian hat factory, the first room one visits is the winding room, where the straw, as it comes from the dyers, is wound on reels. In a second room, the braid is sewed into flat plaits of straw, and, in another, the hats are shaped over iron moulds. In the dyeing-house, which is a large shed open to the air on one side, there are great vats with steam pipes and cold water pipes, so that the water may be made hot or cold at will. About twelve hours' soaking is required to dye black straw, but blue takes only a few minutes. Bleached straw is kept in the dark, so that the sun cannot give it even a tinge of yellow. A Leghorn hat which has grown yellow from wearing will come out as white as snow from a sulphur bath.

The Italian women know all sorts of fancy ways of braiding. Tuscany is the great straw region of Italy, and baskets, fans and many other pretty things, as well as hats, are made there.



1. The First Stage in Weaving a Panama Hat. Panama Hats are woven of the Fibers of the young leaves of the stemless Screw-Pine of Central America.

2. A Panama Hat nearly completed.

The Chinese straw braid comes mainly from Shantung, and the Japanese are now furnishing about two-thirds of the straw used by London hatters. Some braiding is also done in Switzerland and Germany. It is not so long ago that little girls in this country braided their own hats of straw or palmetto, and sometimes earned a little money braiding for market. The people who braid straw in China earn about one cent a day, and their daily stunt is about thirty yards of "split plait."

A factory in Milwaukee, the third largest in America, gets all its straw braid from foreign countries. It comes in forty-yard pieces and this factory keeps fifteen million yards in stock, employs five hundred girls and men, and makes one hundred thousand dozen hats in a season.

THE PANAMA HAT WHICH IS NOT A "PANAMA" AT ALL.

But the most famous straw hat is the Panama, which is not made in Panama at all.

The first "Panama" hat was made in Manavi, Ecuador, some two hundred and seventy-five years ago, by a native named Francisco Delgado, and as Panama was the only market for that region, the straw hats made after the fashion Delgado set came to be known as Panama hats. But Ecuador is not the only source of supply, for they are made in Colombia, Central America, and, indeed, in many places on the west coast of South America. In the West Indies they are called Jipijapa hats (the j is pronounced like h), because Jipijapa in Manavi is one of the towns where they are produced. The hat is constructed of a native grass, or cane, resembling palmetto. The cane is planted, during the rainy season, in low-lying, wet land, and, when it has grown to be four and one-half to five feet high, it is cut, just before the seeds ripen. The straw is then boiled in hot water, dried in the sun, and sorted. For a fine hat, the best straws are selected, dampened, and split between the little finger and thumb-nail into fine strips. It used to be said that these hats were braided by moonlight, and under water, but this is not exactly true, though the best of them are braided by night, usually between midnight and morning, and in the dampest air that can be found. This makes the straws more pliable, so that the braiding is smoother and closer, but, as the worker can spend only about three hours a day on the hat, it takes from three to five months to finish one. The plaiting begins at the tip of the crown; and, when the braiding is finished, the hat is washed in clean cold water, coated with a thin solution of gum and polished with powdered sulphur, to whiten it. It is only the natives possessing quick sight and a deft touch that can do such work at all, but, when done, the hat will wear for years, and can be rolled up and put in the pocket, sat on, or used as a water carrier, without spoiling it.

The fancy hats sometimes bring from $22 to $44 each. The finest ever made were sent to the Paris Exposition by a native named Palma. Two were presented to the Emperor Napoleon III and Marshal MacMahon, by a French gentleman, who paid $193 for them. Palma is dead, but there are other natives who do just as good work as he did.

CHAPTER XI.

The Leather Industry.

A BETTER USE TO MAKE OF SKINS THAN EATING THEM.

IN many stories of shipwreck, we read of the starving sailors being forced to eat the leather of their boots. Unpalatable as that diet may seem, hardly a week passes that most of us do not consume, with a good deal of relish, the same substances that are the component parts of leather.

By boiling the hide, or skin, of any animal in a limited amount of water, it dissolves, and, on cooling, it congeals into a jelly-like substance, called gelatine, of which many kinds of desserts are made.

But skins can generally be put to better use. Instead, they are soaked in water along with certain kinds of barks, or vegetable matter. In these barks, such as the oak or the hemlock, is a substance called tannin, or tannic acid, the same thing that gives tea such a bitter taste when it draws too long. By combining these two substances, the tannin in the bark and the gelatine in the hides, a chemical reaction takes place; the tannin precipitates the gelatine, hardening it. The result is leather. In this manner, though in more technical language, the chemist explains the process of tanning.

A PROCESS SCIENTIFIC, BUT OLDER THAN SCIENCE.

But the art of tanning is older than the science of chemistry. Our ancestors walked in the early dawn of history, in shoes of as real a leather as can be made today. Science has taught us nothing about making leather, except how to do it more rapidly.

As an industry, tanning hides into leather was really never introduced into America. The Aztec princes and warriors who met Cortez when he came to Mexico, wore fine leather boots, and the Aztec shopkeepers sold leather goods to the public. Even the North American Indians preserved buffalo hides by smoking them, though that is not true tanning.

ANOTHER GOOD ACT OF THE STERN OLD PILGRIM FATHERS.

Today the United States leads the world in the manufacture of leather and shoes. For this, thanks are due the Pilgrim Fathers; they and their children fostered the industry through rather drastic measures. For, as far back as 1640, Massachusetts passed a law punishing people who slaughtered cattle and neglected to preserve the hides. Another law punished them for keeping green hides in their possession more than a few days after the killing. But a third law forbade them to do the tanning themselves; the hides must be sold to the local tannery. Nor were butchers, curriers, or shoemakers allowed to tan hides; for tanning, as a distinct trade, must be encouraged. Then the laws dictated to the tanners, in minute detail, how they must prepare their leather. Inspectors, called ''sealers,'' examined all the finished leather, and only if it came up to the standard of excellence demanded by the government was it stamped with the official seal. No shoemaker dared to make shoes out of leather not stamped. Tyrannical as such interference may seem to us now, it is to these vigorous laws that New England owes her rank as the chief shoe manufacturing center of the world.

Though North America slaughters millions of cattle every year, she cannot supply more than a fraction of New England's demand for hides. Shortly after the Revolution hides began to be imported from other countries, especially South America. Whoever has read Dana's *Two Years Before the Mast* will remember how the author went in a sailing ship around Cape Horn to California, where the better part of a year was spent in gathering a full cargo of hides from the cattle ranches along the coast. It was the growing shoe industry of New England that made such long and dangerous voyages worth while.

The demand continues, as strong as ever. In 1910, over six hundred million hides, or skins, were imported into the United States, most of them from the pampas of Argentina; though Brazil, Uruguay, Australia, and China contributed a fair share. Many of these hides went back to those same countries as shoes.

WHAT HAPPENS WHEN CHEMIST AND TANNER JOIN FORCES.

Until the chemist came to advise the tanner, it took about a year and a half to tan an ordinary ox hide. Now it requires only from three to six months. The processes are many and varied; the tanner who prepares shoe leather can no more make fine glove leather than a blacksmith can construct a lady's watch. But the tanning of shoe leather forms the great bulk of the industry.

When the hides are unloaded at the tannery, they are either dry, stiff as sheet tin; or pickled, damp, and salted. First, they are washed in great vats of water. Then, when they have been thoroughly cleansed and rinsed, they are spread over a round, inclined table, called the "beam." Here the adhering bits of flesh, the ragged edges and the tails are trimmed off by means of a sharp knife called the "flesher."

Next, the hides go into another vat full of milk of lime, a chemical which burns out the hair and outer skin, the epidermis, corresponding to that part of the human skin which is raised by a blister. This treatment lasts from four to eight days, during which the hides are moved about and turned twice a day. Then they are drained, spread over the "beam" again, and the hair and the epidermis, now loose, are scraped off with a dull knife. They are then dropped into clean, running water and left there for half an hour or more, that the milk of lime may be washed off.

This process of removing the hair and the epidermis is, in the case of the pickled hides, accomplished in another way. They are hung up to "sweat," for several days, in a warm, moist chamber, until a slight decomposition sets in, which accomplishes the same purpose as the milk of lime.

Heavy hides, intended for sole leather, are now ready for the tanning liquid. Lighter hides, to be made into shoe uppers or any leather that must be soft and pliable, are first soaked and mauled about in liquid manure of the hen, pigeon, or dog. This ferments them and modifies their natural stiffness.

The tanning liquid was formerly made almost exclusively from oak bark, but now hemlock, larch, birch, chestnut and the acacia are used as well. These barks are soaked in warm water and a sort of tea made of them, which is run through a series of vats, its strength being graduated from vat to vat. The bundles of hides are thrown into the first vat, in which the liquor is weakest, then, as the tanning process proceeds, they are moved on from one vat to another, each time into a stronger liquid. As the liquor weakens, it runs into the next vat and stronger flows in. An instrument called a barkometer records the strength of the fluid in each vat, which must be constantly kept up to a certain degree of strength. Meanwhile, the hides are frequently turned and twisted about. This process, for heavy leather, requires several months, but lighter hides are cured in as many days.

To leather which will be subjected to no heavy wear or strain, an entirely different process known as chrome tanning is applied. For this operation, instead of a vegetable liquid, a solution is made from various kinds of mineral chemicals which cure the hides in a few hours.

Still another process, not properly tanning, is known as "tawing." This consists in washing the hides in bran water, then treating them with alum and salt—a procedure which leaves them white and soft, but not so tough as when tanned.

A fourth important process includes the use of oils and fats repeatedly rubbed into the skin. A familiar product of this method is chamois skin, so called because it should properly be made of the skin of the chamois deer. But most of the so-called chamois skin grew on the backs of goats and sheep.

MANY LEATHERS OF MANY NAMES.

Special leathers undergo other and more complicated treatment. The famous Russian leather, used almost exclusively in binding books, is highly prized because it is proof against insects and molds. The odor from one book bound in genuine Russian leather will protect a whole bookcase of books from insects. In tanning this valuable leather, the Russians use yeast, rye flour, and willow bark.

Morocco is another famous book leather. Formerly, it was made only in the Levant, as its name partly indicates; and only the hides of a certain species of native goat could be used. But now Morocco leather is made in great quantities, in the United States, from sheep skins. One peculiar feature of preparing Morocco is, that the skins are sewn into bags filled with a fluid prepared from the sumac plant. The bloated bags are then thrown into a large vat full of a weaker decoction of the same liquid, and agitated and stirred about for several hours.

Cordovan, used in rich ornamentation, is another expensive leather. It was formerly made in Spain, taking its name from the city of Cordova, and was always prepared from the hides of dogs. But genuine Cordovan is rare; the imitations are made from sheep skins.

Shagrin is one of the most valuable of leathers, used in binding very expensive books. To its manufacture the wild ass of the Orient contributes.

Of late, even stranger animals have been robbed of their hides to supply the leather industry with material. The porpoise gives excellent shoe leather; so do the kangaroo, the seal and the alligator. Even the horse contributes his skin for our tan and russet shoes.

OLD WAYS OF AN OLD INDUSTRY.

The manufacture of boots and shoes is an industry that is peculiarly American, for in no other business is the American genius for mechanical invention more brilliantly demonstrated. Machinery performs every one of the one hundred and seventy-five separate operations required in the making of a finished pair of shoes. All this is the development of the past fifty years; before that, every operation was performed by hand.

From the first settlement of the country New England led in shoemaking. Many of the earliest Pilgrim Fathers were shoemakers by trade; forty came over between 1620 and 1650. During the Revolution, what shoes the soldiers of the Continental army wore were made in and about Boston, especially in Lynn and Brockton.

In those days, when a shoemaker had finished his apprenticeship, he ''whipped the cat,'' meaning that he traveled over the country, stopping at each farmhouse long enough at a time to work up the farmer's stock of leather into shoes that would last the whole family until the next year's visit. Finally, as the country became more thickly settled, he set up a permanent shop of his own, and his customers came to him—which was not so sociable, but more profitable. Out of this, long before the first machine was thought of, shoemaking was systematized in the larger towns. One master shoemaker would employ several dozen men, and to each he assigned a special part of the whole operation of making shoes. One cut the uppers, another sewed them together, another cut the soles, and a fourth sewed the soles to the uppers. By so limiting the work of each man to a simple operation, a workman became more expert and the whole work was accomplished in much shorter time. It was probably this specialization that first suggested the possibility of machinery.

The first innovation, a link between hand work and machine methods, came in 1818, when Joseph Walker, of Hopkinton, Mass., conceived the idea of driving in wooden pegs instead of sewing the uppers and the sole together. This method grew to be so popular that peg-making became a separate trade and later, when they were manufactured by machinery, the pegs became so plentiful and cheap, it is said, that Yankee peddlers went about selling them to the farmers as the seeds of a new and superior kind of oats.

STEEL SLAVES OF THE SHOE TRADE.

The first practical machine appeared in 1845; it rolled out the leather, doing in one minute what had required one hour of hand labor. When the hide comes out of the tanning liquor, it is swelled to almost double its normal thickness. To reduce it and render it properly compact, the shoemaker formerly hammered it against a flat stone in his lap, going tediously over the whole hide. This reduction of leather was the first task given to machinery.

After that, inventions followed in a storm. To describe each new invention and its improvements would fill a large sized book. Today, not a single operation is performed by hand, and there are over four hundred separate machines and mechanisms to do the work.

First of all, in the modern factory, there is a machine that solves a rather complicated problem in mathematics; it measures and computes the number of square inches on the surface of each newly bought hide. So accurately does it calculate, that neither buyer nor seller ever questions its answers. Intellectual as this task may seem for a machine to do, its mechanism is quite simple in principle. A roller revolves close to a row of small wheels, against which the hide is shoved, and, as it travels through, the little wheels, are lifted and each one registers the number of revolutions it makes while the leather is passing through; for each wheel, when raised by the leather, contributes to the motion of an indicator on a large dial in front of the machine. By this means, the surface measurement of the hide is automatically indicated, for the number of revolutions of each wheel gives length, and the number of wheels raised indicates width.

On the top floors of the factories are the lighter machines; first, those that cut out the pieces which make the uppers. They really punch them out, as a railroad ticket is punched. Then come many small machines that paste and sew these pieces together. The last of these punch out the button holes, stitch the edges, and sew on the buttons; or they punch out the holes for the laces, fixing in the eyelets at the same time.

Meanwhile, heavier machines, on the lower floors are making the soles and shaping them into those graceful shapes so peculiar to the American shoe. The principle here involved is the same as applied by the cook in punching biscuits out of a layer of dough with a glass.

Next, the sewn uppers are drawn tightly over a last. The machine which performs this duty is provided with a set of automatic pincers, and is familiarly known as ''the nigger'' not because of its black coat of paint, but because a colored man invented it.

Now the stitching machine gets ready to work, for wooden pegs are out of date in a factory. An inner sole has been placed against the bottom of the last and the edges of the uppers turned over it. An outer sole is fastened to this by a few tacks, the edges of the uppers being between the two. The shoe, loosely tacked together, is now placed on the end of a rotatory support, called a horn, which holds it up to the needle. A spool, containing thread coated with beeswax, is carried by the horn, and the thread, with its wax kept soft by a lamp, runs up inside the horn to the whirl, which is a small ring placed at the upper end of the horn. Through it there is an opening for the needle.

As the needle, which is barbed at the point, goes through the soles, the whirl lays the thread into the barb and, as the needle rises, it draws the thread through the soles and the edges of the uppers, forming a chain stitch. As the sewing continues the horn is rotated, bringing every part of the margin of the soles under the needle. This machine, when operated by an expert workman, sews nine hundred pairs of shoes a day.

Finally, the heels, built up and subjected to a pressure of several tons, are nailed on to the soles by another machine which makes its own nails out of a piece of brass wire. After this, the shoe is finished off by numerous little polishers.

By actual tests made by the experts of the old Bureau of Labor, the time saved in the manufacture of shoes by machinery, as compared with former hand-labor methods, has been accurately estimated. It requires over six months, working twelve hours each day for one man to make one hundred pairs of first class, calf skin shoes by hand; machinery does the same work in a little over three weeks. The old method costs $556 for each hundred pairs; the machines do it for $75.

Almost all these machines are of American invention. They are constantly being improved or even superseded by entirely new ones. But most peculiar is the way in which they are marketed. In fact, they are not put on the market at all, for one big corporation, which has bought up all the patents, controls their entire manufacture and rents each machine out to the shoe manufacturers. Lately, however, another corporation has been organized which has hired inventors to create an entirely new set of machinery not covered by the previous patents. Now the two trusts are preparing for a battle royal for what is practically the control of the New England shoe industry.

NEW ENGLAND'S CHIEF INDUSTRY.

As a shoe manufacturing nation, the United States stands at the head of the list. There are in the country one thousand three hundred and sixteen separate factory plants. Without explanation, this statement will mislead. Several years ago there were more plants than there are now, but, with the improvements in machinery, the shoe industry has concentrated into fewer but very much larger factories. Since one machine does so much more work, one factory can now produce more shoes in a day, than a number of factories could, a few years ago.

About one hundred and twenty million dollars are invested in shoemaking. There are about one hundred and fifty thousand operatives; and over four hundred million pairs of shoes are manufactured every year. About three-fourths of this tremendous output is produced in New England and about half comes from the neighborhood of Boston. Obviously, as the American people do not need so many pairs of shoes, a large part of the output is exported to other countries. Estimated by actual value, the United States leads all other countries in exporting shoes. Great Britain excels in numbers, but the average wholesale value of a pair of shoes exported from Great Britain is only $1.11, while the average value of a pair of American shoes is $1.69.

The best customers of the United States are the people of tropical countries; Cuba takes one-third of the production. Porto Rico, the Hawaiian Islands and the Philippines last year bought over a million pairs of American shoes. Argentina, which sends the raw hides, also takes a good proportion.

It is here that the significance of machinery is apparent. If all shoes were still made by hand, competition with the cheaper labor of European countries would be impossible. But American shoe manufacturers employ an army of steel slaves who require neither keep nor wages, and against their labor no human labor can compete.

CHAPTER XII.

Rubber and Rubber Fabrics.

AN ARISTOCRATIC RELATIVE OF A DOORYARD WEED.

IF you have ever noticed the little low-creeping spurge with its milky juice, in old dooryards, you have seen a member of the caoutchouc family; but the india-rubber tree, from which crude rubber is obtained, may grow one hundred feet high and have a trunk as thick as a man's body. There are rubber plantations in Mexico, Central and South America, Africa, and the East Indies, but some of the best rubber comes from Brazil. The quality of rubber depends more upon the way in which the sap is gathered and cured than upon the place where we get it.

HOW RUBBER IS HARVESTED.

The rubber-tree nearly always grows in a jungle far from human habitation, and the owner can depend for labor only on the natives, whose methods are likely to be terribly wasteful. The proper way of extracting rubber is to make a cut in the trunk, and, under it, stick a dab of clay to fasten the tin for the sap. One tree may give from eight to twenty pints, according to size. When the sap has stopped flowing, the natives build a fire to cook the rubber over the burning nuts of a certain kind of palm, which makes a dense black smoke. When the sap has begun to thicken, a small round-bladed paddle is dipped in smoked, and dipped again, until the rubber on it is about two inches thick, when it is cut off. This is called ''biscuit'' rubber, and is ready to be packed in bales and taken to the market.

CRUDE RUBBER GETS DIFFERENT TREATMENT IN DIFFERENT COUNTRIES.

In Nicaragua, they leave the sap alone until the water dries off; then they stew the stem of a kind of morning-glory vine which grows in that region, and add a pint of the liquid to every gallon of sap; this thickens it and forms a sort of india-rubber.

Mozambique rubber comes in balls about the size of an orange, or in the shape of sausage made of strings of the rubber wound round a piece of wood. Lumps of rubber from the Congo are called ''knuckles,'' those from Sierra Leone ''thimbles,'' and those from the Portuguese colonies are known as ''nuts.'' In Angola the natives collect the rubber on their arms, going from tree to tree till the arm is covered, and then rolling the rubber down toward the hand in a ring.

OTHER WORDS THAT MEAN ''RUBBER.''

The Malays and the Chinese have used rubber for many hundreds of years, and our word ''gutta-percha'' comes from the Malay, *gutta* being Malay for gum, and *percha* the name of the tree. The South American Indian calls it ''cahuchu,'' from which we get the word ''caoutchouc.''

OUT OF BITTER POVERTY ACHIEVEMENTS OF UNTOLD VALUE.

But rubber in the rough is soft and unfit for use, and great were our troubles until a way could be found to harden it. And the story of hardening rubber, which is the story of Charles Goodyear, is one of the most inspiring tales of American industry.

This remarkable man was born in New Haven in 1800, and was nearly thirty years old before he became interested in the possibility of making shoes and fabrics of rubber; but, from that time until his death in 1860, he was constantly experimenting with and inventing all sorts of rubber devices. For years he was so poor that he and his family almost starved, and he had to carry on his experiments with borrowed money, at one time being so near penury that he was obliged to sell his children's school-books for $5 with which to buy fuel. He tried baking rubber over brush fires, in the cook-stove, in factory furnaces when the day's work was over—anywhere that he could get a fire. The great trouble at first was, that the rubber was incurably sticky, and, when heated to a hundred degrees, would melt, while, in the cold, it became as stiff as a board. Daniel Webster had a cloak and hat given him by Mr. Goodyear in those early days, and tells how he set them up in a field one winter day, and they stood alone. At another time, Mr. Goodyear hired a room on Gold Street, New York, where he cooked rubber over a little stove, and induced a friend who had a factory in Greenwich Village, three miles away, to let him try experiments on a larger scale there. He used to walk to this factory, carrying his load of rubber on his shoulders. It was at this time that one of his friends said, "If you see a man in New York wearing a rubber coat, cap, stock, shoes, and carrying a rubber purse with no money in it, that is Goodyear."

THE SECRET IS DISCOVERED AND WITH IT SUCCESS.

Finally, he discovered the effect that sulphur has on crude rubber, and convinced the United States Government that rubber mailbags could be made. He got an order for one hundred and fifty, and made them. Owing to some effect of the paint on the rubber, they began to rot, and the handles soon dropped off. Any ordinary man would have given up, but the inventor, determined not to waste the rubber, began some new experiments with what was left of the bags, and found by accident, that when this rubber, treated with sulphur, was dropped on a red-hot stove, it charred as leather does, instead of melting. This made him wonder if heating the rubber to a high degree of temperature would not produce the firm, leather-like substance that he had been trying to make. It did. And after twenty years of work, he filled a room at the Crystal Palace exposition in London, in 1851, with all the rubber devices of which he had been dreaming. There were life-preservers, and air-cushions, and water-bags, and other hospital devices; rubber balls, dolls, cloaks, combs, shoes. The Rubber Court was one of the sights of the exposition.

He once published the story of his invention in a unique book, printed on rubber pages and bound in rubber covers, which looked very much like a parchment book in a leather binding.

OTHER WAYS NOW OF SULPHURIZING.

Rubber is now sulphurized in several different ways. One is to grind up the rough sheets of rubber, which have been freed from impurities, and, placing the bits in a caldron with sulphur, to heat the two together until the sulphur has brought every part of the mass to a uniform yellow. At first the rubber was "cured" by exposing it to the sun for a long time, but this is now done with acids.

THE FIRST SHOES THAT MADE A TRIP TO BOSTON.

Overshoes of India rubber were made long before the Goodyear process was thought of; but they were crude, uncouth affairs that would hardly be received into polite society today; worse still, they didn't keep out water. But gum shoes, such as they were, first appeared in America in 1820, being rather rashly introduced to Boston by a sea-captain who brought them from Para, where they were built up by natives. They were shaped somewhat like Chinese shoes, rudely carved and gilded, and were made by dipping a wooden last, smeared with clay, into the crude rubber until layer after layer had hardened and the shoe was thick enough—too thick, in fact, for comfort, service, or appearance. But no one knew about anything better—they were better than nothing—and, a little later, three hundred pairs were brought from Para, and sold to aristocrats at $5 a pair. It is estimated that during the years from 1825 to 1840 more than one million pairs were sold at this very considerable price. But imagine an aristocrat of today in gum shoes like those!

The first American rubber shoes were made by cutting out the uppers from a sheet of rubber and fitting them over a wooden last, holding them in place by a few threads across the sole; then the rubber sole, or sometimes a leather sole covered with rubber, was fitted on and cemented to the upper. They would not stay on the foot without being tied, and the sheet rubber was likely to be thick in one place and thin in another, so proving to be a very inefficient and altogether unsatisfactory overshoe.

But the thin, light, natty thoroughly waterproof "rubbers" or sandals, that now fit our shoes like a glove, are almost works of art, to say nothing of their other merits. Some of them are even finished in tan or other colors to match shoes, costumes, or complexion!

FROM OVERSHOE TO "CONGRESS" SHOE.

The first elastic cloth was made for the wrists of gloves, and then used for straps of various kinds and for gussets in the sides of cloth shoes. These shoes were, in America, called "Congress" shoes, and could be slipped on without having to be laced or buttoned. In making this elastic webbing, the threads of rubber are stretched on a frame, and the silk, linen, or cotton thread woven into the stretched elastic. If there is to be a pattern printed on the elastic ribbon it is stamped on while the ribbon is partly stretched.

KEEPING DRY IN THE WET.

Rubber overcoats, or raincoats, have experienced quite as radical an evolution as the overshoe. The remarkable feat, already related, of Daniel Webster's cloak that stood upright as well when he was out of it as when he was in it, was duplicated a thousand times; for india-rubber coats, in the infancy of their race, used to have a tiresome way of growing as stiff as a board in cold weather, and sticking, almost melting, when it was hot; they were heavy and ugly, too, and they cracked easily.

In England, as well as in America, inventors had been at work on rubber, and it was there that the waterproof raincoat got its start. MacIntosh hit on the right idea and gave the article his own Scotch-misty name, though he had to change the spelling slightly in the christening.

The cloth foundation for a mackintosh is spread out and covered with layer upon layer of very thin India-rubber paste; the cloth can of course be made into any form desired when the rubber has dried, seams being ''proofed'' with rubber.

Raincoats may now be made over a foundation of silk, or with silk or linen linings, or even lined with rubber in such a way that they can be worn with either side out; and the best are light enough to be carried in the pocket. Inventors have added one thing after another to the rubber coating so that it is as soft and flexible as flannel, and never sticky. A great deal more care is taken, too, in the dyeing and coloring of the rubber, and a rubber coat is made as beautiful, and of as attractive colors, as any other coat.

OLD ENEMIES—OIL AND WATER.

But india-rubber is not the only material used for waterproof clothes. The objection to it, for all-day wear, is that it keeps out not only water but air, and the skin, as well as the lungs, needs air. It keeps in the moisture of the skin also, so that, after a long walk or drive in a waterproof suit, one feels "clammy." Then, too, people like to have coats and cloaks which they can wear in any weather, and so various ways have been devised for making thick cloth, or suiting, more or less waterproof. Sometimes it is treated with chemicals that resist water and tangle the little fine woolly hairs of the cloth together into a kind of felt, and sometimes oil is used in one way or another. Oiled silk is absolutely wet-proof, because oil fills the tiny pores in the fabric, and, as we all know, it will never mix with water even enough to let a drop of water through. This, by the way, is why we use oiled paper for wrapping sandwiches, and lining cracker boxes.

BUT TIME FAILS FOR TELLING ALL.

Rubber is used, and increasingly, in so many thousand ways, especially in the household, that only a few can be mentioned and the process of making them alluded to. Air-pillows, hot-water bags, rubber gloves, traveling bathtubs, even rubber mattresses—where is one to stop enumerating?

The rubber eraser which every one uses is of rubber, ground up and mixed with powdered pumice or silica, and then melted, moulded, and hardened. "Hardening" suggests other articles, made of ebonized rubber, the hard black rubber that is used for eyeglass-frames, atomizers, telephone receivers, etc., and sometimes called black vulcanite. It is made by treating crude rubber with sulphur at a great heat, and whether soft or hard rubber results depends on the amount of sulphur and heat used.

Rubber tubing is sometimes made by joining the two edges of a strip of rubber and cutting them together, and sometimes by squirting from a tube with a stem in the middle, so that the stream of rubber comes out hollow.

The old way of making elastic threads, or bands, was to cut a sheet of rubber into tiny strips, but bands can now be made by filling a metal squirt with partly liquid rubber and squirting the rubber out in a thin thread.

Rubber toys are often made in moulds, into which a crude ball or bag of soft rubber is placed and blown up to fit the mould. There has been such a thing as rubber cloth, made of rubber threads; a yard of it was woven on a hand-loom in 1841. But it is difficult and expensive to make, and thin sheets of rubber, or cloth coated with it, will do as well for any ordinary purpose.

PART II.

Providing Food for Man.

CHAPTER XIII.

The Wonders of Modern Agriculture.

THE IDEA OF A THOUGHTFUL SAVAGE.

THOUGH we honor and perpetuate the names of our great inventors, the man who made the most important invention of all time remains unknown and unhonored. To be sure, there was no Patent Office at the time, and people could not read and write, so there was no way to record the details of how the plow was invented. Probably the first model was not much to look at, either; a clumsy stick with a crook at the end, yet the idea behind it represented the first awakening of that brain power which has led mankind out of savagery into civilization.

Of course, we cannot know exactly where or when the first plow was used, but the logical evidences of science give our surmises almost the authority of established fact. We know positively that our prehistoric ancestors were half-naked savages who roamed about in small bands, entirely dependent on nature for their food supplies; but Nature's resources being rather scant and uncertain, they were occasionally reduced by famines. They lived on the wild animals they could kill with their clubs or arrows, and on the wild fruits and grains they could gather. They were obliged to follow the game in its wanderings or live only in places where vegetation was abundant, for they could control neither of these two sources of food supply.

But, one day, one of these savages, more observant and thoughtful than his fellows, discovered that by prodding up the crust of the soil with a pointed stick he could prepare a spot where food plants would grow quicker and more abundantly than elsewhere. Perhaps hundreds of other savages had disturbed the soil before with pointed sticks, and then forgotten about it. It was to the man who observed the results, who pondered over them and stored them in his memory, and then repeated the experiment the following season with a bigger stick, that the credit belongs. It was not that he had stumbled on an invention, but he had conceived an idea of tremendous importance to all future mankind—the control of its food supply through thought and human industry.

THE IDEA OVERTURNED MORE THAN THE SOIL.

From that moment civilization began. Men were no longer obliged to roam, like beasts, in search of food, for they could make it grow before the doors of their huts. They gradually gave up hunting; they captured a few animals alive, fed them, domesticated them and used them according to their needs, not only as food, but as assistants in tilling the soil. Now men could settle in permanent communities, for the plowshare had opened up to them treasures in the earth. There was enough food for all who would labor, so men increased in numbers and grew into mighty nations. For, without the plow or the great fact that it represents—human industry—there could be no nations, great or small.

Men learned to draw pictures before they could write, and, just as soon as they acquired that primitive art, they recorded the invention of the plow in diagrams. On one of the oldest walls erected by the hand of man, an Egyptian temple, there is still visible a series of drawings representing the plow and the manner in which it was used at the time. It is shown as a crude, bent piece of timber, sharpened at the end, and pulled sometimes by men and sometimes by oxen.

Later on, still before ideas could be recorded in writing, the point of the plowshare was shod with iron, which, of course, made a plow many times more durable and much more efficient. The Bible tells of the Jews, who knew nothing of blacksmithing, going down to the Philistines to have them ''sharpen every man his share and his coulter.''

After that, centuries passed before the plow was again improved. For a time, the nations were too busy robbing one another to trouble themselves with inventions, except in the making of weapons. Then the Romans, having conquered the world, took time to improve the plow again. They joined two pieces of timber at the ends, forming an acute angle, and this point they shod with iron. This was really the first constructed plow.

Crude as it was, the Romans appreciated the importance of this humble implement. Plowing was the only form of labor which a Roman did not consider degrading and leave to his slaves. The greatest generals and statesmen of the empire would often plow their own estates. The Chinese also honor the plow in a similar manner. Every year, when the spring plowing begins, the Emperor of China goes out into the fields and plows the first furrow, to demonstrate to his subjects the dignity of farm labor.

HOW THE IDEA CHANGED CIVILIZATION.

It enables us to realize the significance of the plow by observing that each improvement added to its form corresponds with some great epoch of civilization. Egypt and Rome, two great civilizations, each improved the plow. Then, after the barbarians of the North conquered Rome, the world plunged back into barbarism for over a thousand years. Nothing is heard of the plow during this period. The great lords of feudalism considered agriculture a degrading vocation, fit only for serfs and slaves. Only the sword was honored, and, consequently, the world remained in darkness.

The Dutch peasants of the North were the first to emerge into the dawn of modern civilization. Straightway they improved the plow. They made the moldboard, which turns over the furrow, curved in shape, so as to open up a wider furrow. They also made the beam, by which the plow is drawn and added the two handles by which the plowman guides.

EVOLUTION OF THE IDEA.

This was the model, the first suggestion of a modern plow, which was imported into England in 1730. It is an important year, for modern agriculture began then. A man by the name of Howard began manufacturing these Dutch plows and sold them to the farmers. His was the first plow factory, and it still exists.

Since then, hardly a year has passed that some improvement in the plow has not been attempted. Science began demonstrating what the plow did, or what it really should do, to the soil: viz, to break and pulverize it, to render it soft and mellow, to the end that air should circulate to the greatest possible depth, to exert its beneficial action on the mineral and organic matter which nourishes the roots of the plants.

With this knowledge, inventors knew what they must strive after. Naturally, iron cuts deeper than wood. So they began making the share of cast iron. But cast iron is rough and brittle. So, in 1803, Robert Ransome patented a ''chilling'' process by which he toughened the iron. This made it more durable as well as more efficient than wood.

THE IDEA COMES TO AMERICA.

About this time came the Napoleonic Wars and England again paid more attention to sword blades than to plows. So, as a natural result, the recently freed American colonies, having nobody to fight with, took up the plow; and since then its chief improvements have been registered in the United States Patent Office. At first, however, American farmers were strongly prejudiced against iron plows. They believed that iron poisoned the soil and encouraged the growth of weeds.

Like the ancient Romans, American statesmen have honored the plow. Thomas Jefferson experimented with it and, on paper, suggested possible improvements. After him came Daniel Webster, who sought to perpetuate his name as a maker of plows. He made one in 1836, on his estate in Massachusetts. It was over twelve feet long and turned a furrow eighteen inches wide and twelve inches deep. He plowed with it himself, but, as he needed several men to assist him in guiding it, and it required several yoke of oxen to draw it, his fame comes down to us solely as a statesman. Webster once declared that he felt prouder over the construction of this plow than he did over any of his achievements in Washington; but experts still maintain that his speeches far surpass his plow.

An early difficulty was in tempering the plowshares without warping them. But, in 1863, John Lane took out a patent on soft-centered steel, which is the process by which the best plows are still made. A bar of soft iron is placed between two steel bars, and the three, pressed together, are rolled into a plate out of which the share is cut. The soft center not only prevents warping, but it renders the whole share as tough as the blade of a sword.

WHAT AMERICA DID TO THE IDEA.

From this point onward, it is impossible to enumerate all the useful improvements made in the form of the plow. For almost every kind of soil there is a special plow, differing in the set of the share or in the depth of its cut. One type is adapted to hillsides, another for irrigation farms, another is more suitable for prairie farms. And there is a kind that digs deep into the subsoil without turning a furrow.

But, fundamentally, they are all more or less alike; the general type is the steel walking-plow, drawn by two or three horses and guided by the plowman, who walks behind. Such is the plow used by the average American farmer with his farm of less than one hundred acres. But while this farmer tills only his few dozen acres, the greatest demand is likely to be for the small, steel, walking-plow with the single share.

THE IDEA GOES "OUT WEST" AND GROWS WITH THE COUNTRY.

For in the far West there were indications of a future change. In California, Washington, Kansas and several other lately settled States, there were grain fields, owned by single men or corporations, so vast that it required hundreds of walking-plows to till them. Here were new needs in plow invention to be met. So inventors first mounted the plow on wheels—the sulky-plow. Then they added one share after another, evolving a form which is called the gang-plow. Each additional share saved the labor of one man by plowing another furrow. Later, a steam traction-engine was invented which could take the place of the horses. By such means two men could plow from sixty to seventy acres a day. There is now a hundred-horse-power engine which plows, sows, and harrows, at the same time, a strip thirty feet wide, at the rate of three or four miles an hour, covering over a hundred acres a day. It does the work of fifty men with teams.

Apparently, such tremendous farming will, in the future, put the small farmer out of business. But that danger is not immediate. As yet, steam gang-plowing can be profitably done only by grain growers, and especially wheat growers. The reason is plain—it does not pay to plant more than can be reaped, and it is only in the grain crops that reaping can keep pace with such plowing. So, while cabbages, tomaties, and tobacco leaves must be gathered by hand, the scarcity of seasonal labor will keep down their production, and the small farmer is safe.

THE INSEPARABLE COMPANION OF THE PLOW.

Inseparable from the plow, almost a part of it, is the harrow. It is to the plow what the rake is to the spade. After being thrown up by the plow, the heavy clods must be broken and pulverized. Also, after the seeds have been sown, they must be covered over; and sometimes the harrow does that.

The ancients, and presumably our savage ancestors, would accomplish this by dragging the branch of a tree over the furrowed field. Here again the Romans improved over old methods. They constructed a timber frame, oblong or square in shape, resembling the gate to a pasture. Through the timbers of this frame they drove big spikes; and had a yoke of oxen drag it over the fields, combing down the furrows. This type of harrow is still in use in many countries, just as the log plow of the Egyptians is still employed by unprogressive peasants. But the harrow has changed less than the plow, since the time of the Romans. In principle it remains the same.

There are so many varieties in form, however, that it takes a whole volume of cuts, issued by the Patent Office, to record the numerous improvements. There are harrows with straight, fixed teeth, driven through a wooden frame work—a series of ordinary rakes, or combs. There are others with round, steel disks in one row, set aslant, which cut instead of raking. Some drag knives, or blades, that also cut the clods. Others are set on springs and rise automatically when they strike stones, or logs, or tree stumps. And there is the orchard harrow, consisting of two sets of disks, each attached to the end of a cross beam. This harrow is dragged between the rows of trees, the horses and plowman walking between the rows, away from the branches; but the disks at the ends of the beam pass along the soil close to the tree trunks, cutting the clods under the branches.

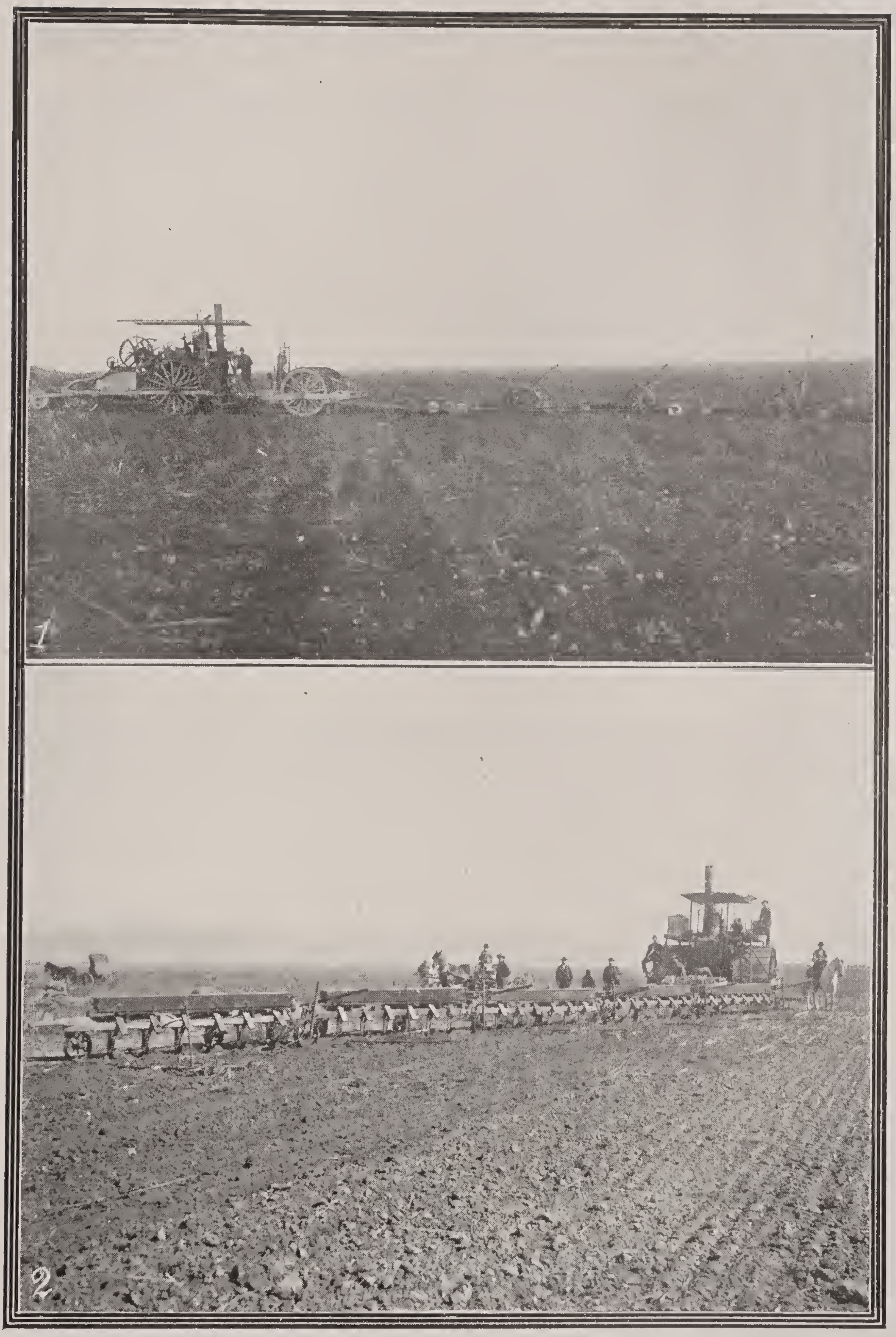
There is one harrowing machine a hundred feet in width, capable of covering three hundred acres a day. Greater efficiency than this is not needed at present, even by the great corporation farmers in the West. For the plow and the reaper cannot keep pace with such rate of progress, and, as all these implements must coöperate closely, the one of least capacity sets the pace.

SOMETHING FOR THE FARMER'S WIFE AND CHILDREN TO DO.

In the olden days, when the degraded serf of the soil plowed with an ox and a sharpened log, it was all he could do to cover a couple of acres a day. As he finished his small tillage, his wife and children would follow and scatter handfuls of seeds broadcast over the soil. It required but little effort to sow as much ground as the blunt nose of the old log-plow could turn over.

EVEN THE FARMERS THEMSELVES FELL BEHIND.

But then came the modern plow. The women and the children with the seed bags found it necessary to quicken their pace. When finally the sulky and the gang-plows appeared, even men could not keep up



MODERN FARM MACHINERY.—1. A gang of plows. 2. Planting seed by machinery.

with them in casting seeds; that method became ridiculously inadequate. Then came the real demand for machinery to do the work.

CASTING SEEDS WITH IRON HANDS.

The idea of sowing seeds by machinery is an old one, but, until the improved plow made it an economic necessity, the idea lay dormant, undeveloped. A sort of drill-plow was used in Assyria, thousands of years before Christ. Only crude drawings on the walls of old ruins tell of this early invention, so we do not know more of its operation than that the seeds leaped out of a hopper hanging just behind the plow, and fell into the furrow as it was made. The idea was plainly there, like a seed in a parched desert, ready to sprout under proper conditions. But such conditions could not exist where invading armies tramped across the land at short intervals, plundering and burning, or where tyrannical satraps robbed their toiling subjects of the fruits of their labor for their own selfish pleasures.

But, with the awakening of popular freedom and establishment of personal security, these germ ideas began to develop. The Dutch plow was introduced into England in 1730; the next year an Englishman, Jetro Tull, wrote what may be considered the first book on modern agriculture, "Horse Hoeing Industry." In this work he maintained that grain should not be broadcasted, but drilled in rows. Later, he designed a machine to drill three rows of turnips or wheat at one time. Undoubtedly the new plow had suggested it to him.

From this time on, many inventions of this nature were made, but they remained for the most part, on paper. It was only after it had been practically demonstrated that the reaper would displace the sickle, that farmers saw the need of sowing by machinery.

In 1840, there began a rush on the Patent Office with devices and improvements for seeding machinery. Again Americans pushed Englishmen aside and took the lead. J. Gibbons, of Adrian, Mich., patented a cylindrical roll with cavities through which to drop seeds in regulated quantities—a device which later became obsolete in principle.

MANY INVENTORS—TWO TYPES OF MACHINES.

If the names of the inventors who have subsequently experimented with seeders were printed, they would present the appearance of a telephone directory. There are now even more types and kinds of such implements than there is diversity among plows. But they may all be divided into two general classes—the broadcast seeders and the drills.

The broadcast seeder drops the seeds uniformly all over the soil. Hay, clover, and similar grass crops are planted in this way. The drill deposits the seeds in rows, continuously or at regular intervals, or even in hills. Nearly all the food crops are so planted.

One of the first seeders, which is still in use, was the wheelbarrow broadcaster. As its name indicates, it resembles a wheelbarrow; on the frame behind the wheel rests a long, wooden trough, crosswise, with holes in the bottom. This is the seed box. The machine is pushed by hand; as the wheel revolves, it agitates a rod, or a set of brushes, inside the box, and so causes the seeds to drop through the holes at a uniform rate. The same principle is applied on a larger scale. The seed box, about six feet long, is on two wheels and is drawn by a horse. Behind is attached a big rake which covers the seeds as they fall.

Other machines, more complicated, have iron disks set aslant just before the seed-spouts. They open small furrows of a regular depth into which the seeds drop. Or, instead of the disks, there may be small hoes, like plowshares, which accomplish the same purpose. The seed-spouts, set in a row under the seed-box, may be regulated to drop the seed continuously, or to drop it at intervals, thus making either continuous drills or hills. The distance between the sprouts, which may also be regulated, determines the space between the drills. Some of these machines drag short chains behind each spout, used instead of a harrow, to close the furrow. Others drop fertilizers from the sprouts with the seeds.

Then there is the potato-planter, which, of course, acts rather differently. It consists of a wheel-mounted frame that carries a seed-box, and, usually, a receptacle for the fertilizer. The cut potatoes are fed by a valve plate into a chamber in which revolves a wheel with spikes sticking out from its rim. Each spike, as it passes, impales a seed cut and carries it over to the seed tube, through which it falls into the furrow. By this method, an acre can be planted with potatoes in a little less than an hour and a half; by the old method, by hand, it took one man twelve hours to do the same work. Thus it does the work of eight men. In onion planting the gain is still greater. Formerly it took one man, using a bottle with a hole in the cork, forty hours to plant one acre; the drill does the same work in one hour and a quarter.

INSURANCE AGAINST STARVATION.

The plow stands as the first implement of agriculture, but of all the agricultural devices and machines that have been invented since the first modern plow was manufactured in 1730, foremost and above them all comes the reaper. It has produced even greater results than the cotton gin, for where the one has given us cheap clothes, the other has insured us forever against famine.

With all the improvements in plows and seeders, their efficiency was limited by the fact that every stalk of grain must be cut by hand, and that within a period of from ten to fifteen days. Here was the great obstacle to further progress. Inventors saw it and began to ponder.

ANOTHER IDEA WE MAY THANK BARBARIANS FOR.

Here again, we find an idea that glowed for a moment far back in the early dawn of history and was soon extinguished. But, strangely enough, this great and most valuable idea did not originate among the civilized people of the time. It was the barbarian Gauls of northern Europe who first conceived the idea of reaping their grain by machinery. Several Romans writers tell how the Gauls constructed a huge wagon, a big box on wheels, which was pushed through the standing grain, from behind, by a yoke of oxen. Along the front rim of the box was a row of spikes, a rough comb, which tore off the heads of the grain and allowed them to drop into the box behind. To clean a field, this wagon had to be pushed over the same ground two or three times.

Soon afterwards, the Gauls learned from the civilized Romans the art of living by plundering others, and so forgot all about their box-reaper. For hundreds of years, until the middle of the last century, the sickle was the only instrument for reaping.

HOW THE IDEA LIVED AND CAME TO ENGLAND.

Again England took the lead, but only to let American energy finish what she had begun—perhaps not because English inventive genius is inferior, but because the broad American prairies and the high cost of labor made the demand for a reaping machine more imperative here.

Nothing so well illustrates the vitality of an idea as the invention of the reaper. The barbarian Gaul and the rude reaper evolved by his crude brain were both swept away, leaving no trace behind, save for a fleeting impression left on the mind of a Roman writer, who also disappeared, leaving after him only a ragged manuscript. Through these means the idea was carried down the centuries to modern times, finally to flourish at its best in the wheat fields of California.

For it was obviously the description of the Gaulish reaper by the Roman historians that suggested the first experiment in modern times. In 1778 an Englishman, William Pitt, made just such a cart to be pushed from behind by a yoke of oxen, but, instead of the simple row of spikes on the front rim, he made a cylinder of spikes, like the cyinder in a music box, to revolve and, tearing away the heads of the grain, comb them over into the wagon. This principle proved impracticable, but it set others thinking.

Many other experiments followed. Sharp edged, revolving steel disks, set horizontally on a wheeled frame, which should be pushed into the grain and cut the stalks as they advanced, were tried next. This principle also failed.

Then, in 1808, a Mr. Salmon invented the principle of cutting which was afterwards to succeed; a row of oscillating knife-blades over stationary, steel tongues, acting like scissors. At first this cutter did not bite into the stalks, but, in 1822, another inventor, Henry Ogle, added the revolving reel, a frame of light wooden rods, somewhat resembling the paddle wheel of a river steamboat, set in front of the cutter. This reel, as it revolved, swept the standing grain in against the blades. These parts still survive in the modern reaper of today, but the combination was still incomplete. The grain tangled as it fell.

Finally came Patrick Bell, who supplied the missing part; he added a moving platform behind the cutter which should receive the fallen grain and sweep it to one side, out of the way of the machine. Bell's reaper worked. It was manufactured, and several Bell reapers were shipped to America. Had the demand for a reaping machine been as imperative in England as it was here, it would undoubtedly have been improved and become popular there.

ON THIS SIDE THE SEA—AND SOMETHING HAPPENS.

The scene of action now shifts to this country. Who really constructed the first practical reaper is still a matter of dispute, but the honor rests pretty evenly between Cyrus McCormick, the son of a Virginia farmer, and Obed Hussey, an eccentric old sailor with a natural taste for mechanics. Hussey was experimenting with a machine to make candles, when a friend asked him why he did not turn his attention to reaping machines.

"I thought there was such a machine," he said. He set to work and, in 1833, obtained his first patent.

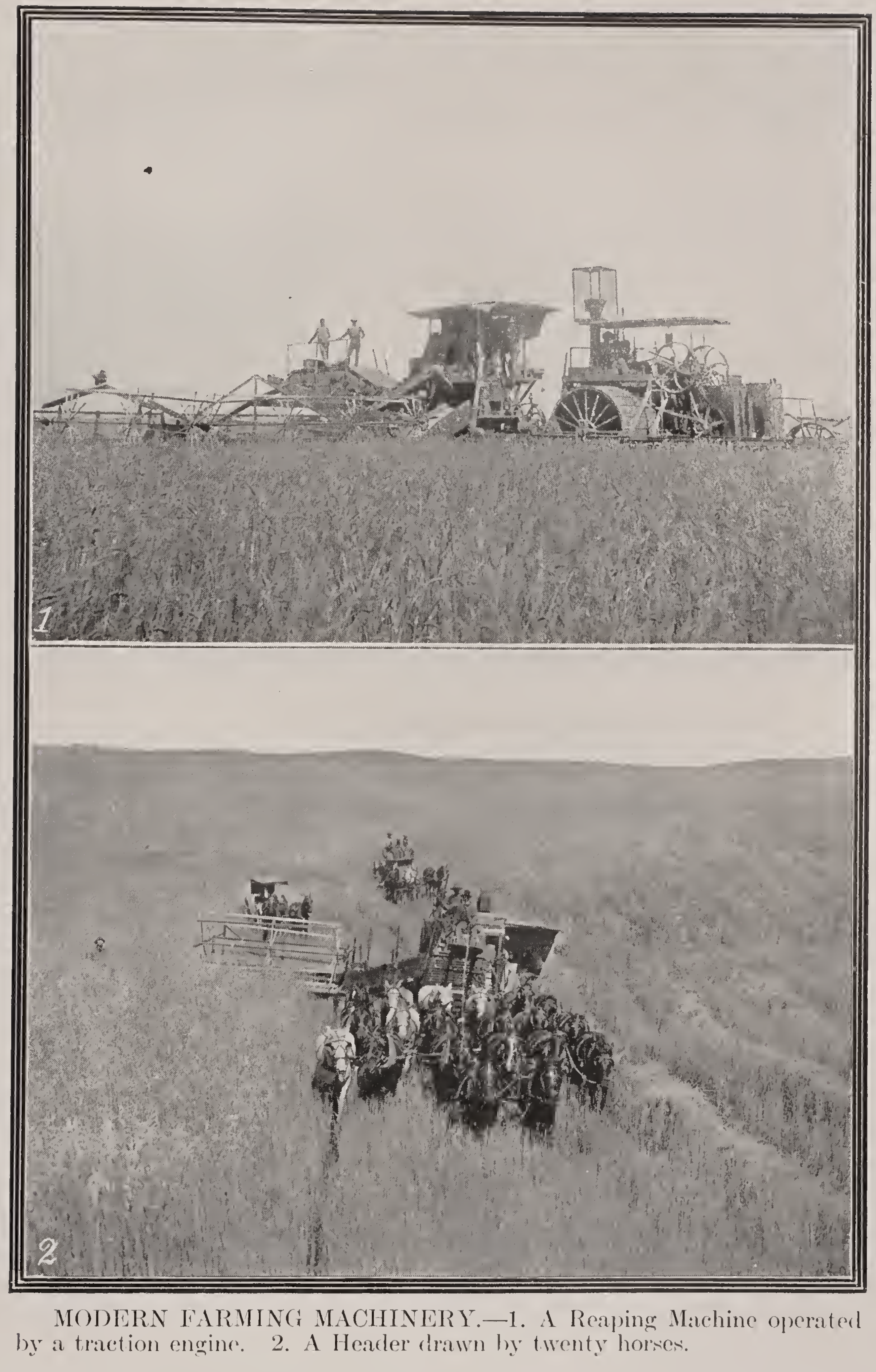
But McCormick, who got out his patent only a year later, had successfully operated a similar machine in 1831, before a crowd of over a hundred people, among whom were some prominent persons of the time. Accounts of the event have been repeatedly given.

McCormick, who was then a mere lad of twenty-two, drove his machine out into a neighbor's field; it was a great, clumsy affair, rattling like a load of loose bricks. Those of the crowd who did not take it as a joke were openly hostile, for they had the prejudice of the day against all machinery, believing that it would take away their employment.

The field was rough and the reaper behaved badly, cutting irregularly and destroying some of the wheat. The crowd hooted and the owner of the field shouted to McCormick to stop; he was making a mess of the crop. But, just as the demonstration seemed about to end in a failure another farmer, the Hon. William Taylor, also a prominent politician of the day, came forward and said:

"I'll give you a fair chance. That next field is mine. Tear down some of the fence and drive over. Have another try."

Mr. Taylor's field was more level. Young McCormick drove his machine over the boundary and cut



MODERN FARMING MACHINERY.—1. A Reaping Machine operated by a traction engine. 2. A Header drawn by twenty horses.

the grain successfully for four or five hours. He reaped over six acres of wheat in less than half a day, as much as six men with scythes could have done in the same time. Such events, rather than battles, mark epochs in history.

At that time, both McCormick's and Hussey's machines were crude and imperfect, workable only over level fields. Both were little more than slight improvements over Bell's machine, which they very much resembled. Both included the reciprocating blades. At a trial test made in England between the two, some years later, McCormick carried off the prize. But the test was not considered conclusive, for Hussey's machine had been operated by a man who had never seen it before. Later, the two machines were matched again in this country, and then Hussey won the medal. And so, for many years, the two inventors were constantly competing with each other.

ANOTHER MACHINE THAT WENT WEST.

But, of the two rivals, McCormick was the most enduring fighter. Hussey began diverting his attention to plows. With him, invention was a hobby; with McCormick, it was business. McCormick knew better how to market his genius. He had the foresight to realize that it was on the Western prairies that the demand for reapers would be strongest; so, against the advice of all his business friends, he moved his headquarters to Chicago, where he began manufacturing his own reaper. Because of this foresight and his tremendous energy, it is practically his name alone that is associated with the invention of the reaper. Today that great manufacturing corporation known as the International Harvester Company is under the management of his son.

HOW THE REAPER HELPED US TO WIN THE WAR.

It was the Civil War that first demonstrated the economic significance of the reaper. The Union armies almost drained the country of its labor. European statesmen declared that we must soon be starving for bread. Yet we not only had enough bread to feed ourselves throughout the war, but we shipped as much wheat abroad as ever. As since explained, the cause is simple.

When the boys had left the farm to go to the war, the old people found themselves facing the difficulty of harvesting the crop. Not only their own, but their neighbors' sons, were away. The crops seemed doomed to rot. Then the old farmer remembered the talk about reapers and he bought one. It more than did the work of the boys at the front. When spring came again, he planted as much wheat as before, for now he knew what his reaper could do.

THE REAPER'S LINEAL DESCENDANT—THE HARVESTER.

When the reaper first entered the service of the farmer, it did no more than cut the grain, leaving it lying in a swath behind it where men had to follow to pick it up and tie it into sheaves. But the workers performing this tedious operation were also soon to be emancipated.

HOW THE REAPER BUILDS OUR CITIES.

The logical results from the invention of the reaper can be followed through our economic structure almost indefinately, growing more startling at each step. Suppose that we still had to reap our grain crops by hand. To harvest the wheat crop alone would, by the old methods, require half the men of the nation. Five men with reaping machinery now do as much work as one hundred used to do with scythes. Formerly it consumed three hours' labor to raise one bushel of wheat. Now the same work is accomplished in ten minutes.

It was the reaper that made it possible to cover all our Western prairies with grain fields. Without it, buffalo herds would still be roaming the vast tracts between the Mississippi and the Rocky Mountains. Because of the reaper, we have become the greatest wheat producing country in the world. After the wheat came the railroads, to carry it to market. Then followed the passenger traffic that brought settlers, who either planted more wheat or went into other agricultural enterprises. In this way were developed the great centers—Chicago, St. Louis, Cincinnati, Minneapolis, St. Paul, Kansas City, Omaha, and a hundred other smaller cities, a large part of whose development is due to commerce in wheat and other grains.

But what is true of all these cities is true of every other American city, though more indirectly. In times gone by, and even now in unprogressive countries, fully 90 per cent. of the population lived in the rural districts. They must raise the food; only about ten per cent. could be spared for the vocations of the city.

The United States is today one of the principal agricultural countries in the world. We produce even more wheat than Russia, whose population is greater than ours. Yet, according to the last census, almost half of our population lives in the cities and towns, following non-agricultural pursuits.

This trend of the rural population toward the cities is exactly contemporaneous with the coming of the reaper. Moreover, it is just in that part of the country where the reaper is driven by steam, on the Pacific Slope, that the growth of the cities has been most rapid.

If one man with a reaper can do the work of twenty, it follows naturally that the other nineteen must find other work. They have done so; now they are engaged in the factories and the mines, making us as important as a manufacturing country as we are in agriculture.

Without the reaper, these men and their families would now be engaged in the brutalizing labor of the old time country estate, sweated by landowners sixteen hours a day, degenerating into a class of heavy, dull-minded peasantry, such as now inhabit Russia and India. Ours is the only country which has never had a peasant population.

It is this emancipation from the brutal hand-labor of the soil that attracts immigration to our shores. These people come from countries that possess, most of them, some degree of political freedom. But people may have political liberty and still be the slaves of toil. The reaper and what it represents, all agricultural machinery, has begun, at last, to furnish the gift of economical freedom.

A CONTRIVANCE OF TWO ILLINOIS BROTHERS.

Just before the Civil War, there were two young farmers near DeKalb, Illinois, brothers by the name of Marsh, who conceived the idea of lightening harvesting labor by tying the sheaves of wheat before they were dropped off the reaper platform. These brothers rigged up a contrivance on their own machine by which the movement of the endless platform behind the cutter was reversed. Instead of throwing the cut grain off to the side, this device lifted it up to a second stationary platform above the wheel where one of the brothers could stand and tie the sheaves as the grain came up to him. The scheme worked so well that they could accomplish almost twice as much work as before. At first they were satisfied with having accomplished so much, and it was only by accident that, two years later, a neighbor suggested patenting their contrivance and getting capital interested in its manufacture. So appeared the first harvester and binder.

At the first public demonstration of the Marsh harvester, there was strong protest from the farmers.

They declared that the machine set too hard a pace for the sheaf binders. In answer, the Marsh brothers had girls mount the platforms of their machines and tie the sheaves. At another time, one of the brothers bound a whole acre of wheat in an hour, while the other drove. This achievement made no special impression on the crowd that witnessed it, but it interested a capitalist who heard of it later. He visited the Marsh brothers and made them a proposition, the result of which was the beginning of an important industrial enterprise.

From the act of lifting the grain to a platform, to binding it as well, was only another step in the further development of the harvester. At first, the complicated mechanism which tied the knot used wire, but this wire, which would often break into bits, would mix with the straw and injure the cattle feeding on it. Then twine came into use. Here is illustrated again what big results may come from apparently insignificant causes.

Ordinary twine was too expensive. After years of experimenting, sisal hemp which is grown in Yucatan, was found most suitable. Now the demand for sisal hemp for binders alone is so great that the planters in Yucatan, formerly a few half impoverished hacienda owners, have become semi-land-barons. The United States now buys from them about eighteen million dollars worth of sisal hemp a year, so that Yucatan has become one of Mexico's most prosperous provinces. And this only for the bit of string that binds each sheaf.

The next process in order is the threshing of the grain, but the developing of threshing machinery began long before the binder was thought of. As far back as 1836, a patent was issued on a machine that worked fairly well, but it required the reaper to emphasize the need of it. When the reaper began sweeping over whole acres of grain in a day, the flail became an obsolete instrument, and the old patents were taken up and improved.

Usually the thresher is run by steam power, for being a stationary engine, as a rule, the problem of traction need not be dealt with. Also, the straw may be used as fuel.

The grain is fed into a hopper, from which it drops into the actual threshing machinery, a toothed cylinder revolving furiously within a similarly toothed concave. The teeth of the cylinder and the concave fit into each other so closely that the space between them equals exactly the thickness of a grain. Here the straw is thoroughly beaten and the grains shaken from their husks. The straw then passes over oscillating screens which shake down the grain. A regulated blast of air, driven upward through the screens by revolving fans, blows the straw and chaff up through a funnel and on to a stack.

In some western States, notably California, where the climate is unusually dry, the sheaves of grain do not need to be cured. There the reaper and the thresher are combined in one machine. This eliminates the binding altogether. When the cutters have performed their work, automatic rakers gather in the grain and carry it to rows of knives, where it is at once headed. As the heads drop into the thresher and the grain into sacks, the sacks are sewed up and fall on the stubble, to be picked up later by wagons drawn by a traction engine. In one operation the grain is reaped, threshed, and sacked for market.

By the old fashioned method, the flail, one man could thresh and clean about seven bushels of wheat, eighteen bushels of oats, fifteen bushels of barley, eight bushels of rye, and twenty bushels of buckwheat, in a day. An average thresher will dispose of from five hundred to a thousand bushels of wheat in a day, or twice that amount of oats. Therefore it does the work of over a hundred men with flails.

There are also threshers adapted to peas and beans, but they differ from the grain threshers in having two cylinders operating at different speeds. This is because peas and beans do not cure uniformly; some pods will be drier than others. So one cylinder is adapted to the very dry pods, while the other, rotating at a higher speed, takes the greener pods. The second cylinder would break the dry pods, but, before they can reach it, the first cylinder disposes of them. Some of these threshers have a capacity of a hundred bushels of clean seed in an hour. Another machine, similar to the pea and bean thresher, hulls clover seed at a rate of from ten to fifteen bushels of cleaned seed an hour.

THE GREATEST WORK OF THE HARVESTER.

We come now to the harvesting of our most important crop—maize, or, as we call it, corn. In the production of corn, the United States stands preëminent. Although this country also raises the largest wheat crop in the world, the corn crop is almost four times greater, and about 75 per cent. of the whole corn production of the world. In 1909, over two and one-half billion bushels of corn was raised in the United States.

To be sure, this is not, like wheat, a direct food crop. Most of it goes to the feeding of cattle, pigs, and poultry, and we consume it in the form of beef, pork, and dairy products.

GETTING IT READY TO BE A FOOD.

Though corn is distinctly a grain, it has been more difficult to harvest it with machinery, on account of its peculiar form. Corn-harvesting machinery is still, in part, in the experimental stage, and differs entirely from that used in the harvesting of the other grain crops.

Formerly, and even now to a great extent, the farmer cuts his corn by means of a corn-hook, which is a curved blade standing out from the end of a handle, like a fire-hook.

WHAT EVERY FARMER COULD MAKE FOR HIMSELF.

The first improvement on the corn hook was a device rather than an invention, since every farmer could easily make it for himself. It was a sled with a steel blade protruding obliquely from one side of the platform. As the sled was hauled down the rows of corn by a horse, the blade severed the stalks. Some sleds had blades on both sides, and still others had two in front, in the middle, forming an inward acute angle, the sled being drawn by a shaft on one side. With most of these sled-harvesters the driver rode on the platform, gathering the stalks into his arms and so guiding them to the blades. It was most exhausting work, beyond the strength of the average man. So a harvester was made with iron arms into which the cut stalks would fall and remain in an upright position, the driver throwing them to the ground when the arms were full. The more perfect machines now tie these bundles with twine, and leave them in the field to be cured.

EARS, NOT STALKS.

But in the corn belt, where the stalks are not used as fodder, the crop is raised for the ears alone. So a machine was constructed to pick only the ears, leaving the stalks standing, and within the last few years, it has attained a partial success. The machine, which is on wheels and is drawn by horses, passes down the row and allows the stalks to slip in between a pair of inclined, corrugated rollers that strip off the ears; these fall on a conveyor below to be carried back, either to a husking machine, or to a wagon accompanying the picker. Unfortunately, this machine injures the stalks, so that, unless it is improved, it will become obsolete as soon as farmers learn the economy of raising cattle on the stalks that are now wasted.

STALKS AND EARS BOTH.

Where the farmers do use their corn stalks as fodder, there is a machine which now handles the crop fairly well. This is the combined husker and shredder, invented about twenty years ago. Of course, only the shocked corn, after it has been cut and cured, can be handled by this machine. Like the hay press, it resembles some sort of fire-fighting apparatus. On the top are two little cogs turning against each other. Into them the stalks are fed, and the cogs grind them into pulp, passing them on to sets of knives that finish the work by ripping them into shreds, so fitting them to be stored in the silo. But every time an ear strikes the cogs it snaps off and drops on an inclined chain of husking rolls. These rolls are sets of small, steel cylinders that turn against one another. As the ears fall on them, the husks are nipped by the cylinders, pulled off, and dropped on a conveyer, which carries them back to the shredded stalks. The husked ears travel on with the chain of rolls until they are pushed off into an elevator, and dumped into bins. The larger machines of this pattern will clean up in one day the fodder from fifteen acres, and husk eighty bushels of corn in an hour.

GETTING THE CORN AND COB APART.

Finally come the corn shellers of several sizes and shapes. In the old days, the farm-hand rubbed the ear up and down against the edge of a shovel and grated the grains off into a tub. Then somebody thought of boring, in a plate of sheet iron, a hole just the size of the cob. By driving the ear through the hole with a mallet, the kernels were ripped off.

One of the most modern shellers contains a cylinder cage, made of horizontal, steel rods set so closely together as to allow room only for dropping the grains. Inside this horizontal cylinder a spiral fan revolves. The vanes of this fan almost reach the sides of the cylinder, but not quite, for, between them, is space for a cob. The fan revolves rapidly, and, as the ears of husked corn are injected into the cylinder, they are violently beaten about against the rods that form the sides of the cylinder. This knocks off the grains, which drop between the rods into a bin below, at the rate, in the best machines, of eight hundred bushels an hour.

The present disadvantage of much of this corn-machinery is its costliness. But, in some corn sections, this is solved by the custom harvesters. One man, who perhaps raises no corn himself, owns the machinery and does the work of his neighbors, one after another for hire. Much of the wheat harvesting is also done in this fashion.

A BROTHER TO THE REAPER.

The reaper gave us not only bread, but meat and milk. For some time the reaper was used in cutting both grain and forage. Then came separate machines for each purpose; the mower grew quite distinct from the reaper. Unlike the harvester, into which the reaper evolved, the mower remains a comparatively simple machine, drawn by one or two horses and guided by one driver. The mower is like the primitive reaper, without the platform behind the cutter to receive the fallen grain. Instead, there is a set of steel fingers which roll the hay or grass, after it is cut, into windrows.

CHILDREN OF THE REAPER'S BROTHER.

Of course, when hay, or peas, or clover was cut by hand, hand-rakes and pitchforks were quite good enough to finish up the work. But the mower brought after it other devices; the horse-rake, a huge rake eight feet wide, set between wheels and drawn by a horse, which hauls the cut hay to the stacks; the hay-tedder, eight big forks suspended between two wheels, which traverses the field, stirring up the hay in the process of curing, so that it may be thoroughly ventilated and get all parts exposed to the sunlight; and the automatic pitchfork, the fork hay-loader. This implement is designed to be attached to the rear of a wagon. As the wagon rolls over the field, the fork hay-loader, an endless apron to which the forks are attached, rakes up the hay and lifts it into the wagon, taking up windrows as well as the evenly scattered hay.

Then there are machines for stacking the hay; sweep rakes and hay stackers. These two are partners, working together. The sweep rake looks like a fence-gate on small wheels. It dips under the hay, lifts it up and drops it down again on the teeth of the hay stacker, then backs away. Then there is the hay stacker, which resembles a light derrick with an apron before it, which lifts up the hay left by the sweep rake and hurls it high up and backward, over its shoulder fashion, on to the stack. When that is high enough, the stacker moves away to the spot where the next stack is to be built and continues the work, lengthening its frame as the stack rises.

Just what these machines mean in saving human labor can be estimated from the fact that, formerly, it required eleven hours for one man to cut and cure a ton of hay, but the same task is now accomplished in one hour and a half by modern methods. To do it by the old method now would entail a cost of eighty-three cents a ton, while the actual cost is only sixteen cents. In the actual mowing, the saving is still greater. The mower cuts an acre of hay in a little over an hour. With the scythe, it would take seven hours and twenty minutes.

Finally, after the hay has been cured, comes the baling press, which finishes the work by preparing the hay for shipment or storage. There are various types of presses, but the better kind resembles somewhat the hook-and-ladder apparatus of a fire company. At one end is a compressing frame into which the loose hay is stuffed. Two horses bend the apparatus to one side, and then, by walking around in a semicircle, they turn it to the other side, working a big lever; and the box, or frame, is pulled in at the end, compressing the hay into a bale, and holding it there until it is corded. Such a machine bales eighteen tons of hay in a day. Hay, when stacked, weighs about four or five pounds to the cubic foot. The baling press increases its density to over twenty, sometimes thirty, pounds to the cubic foot. Specially designed presses, used in baling hay for export, secure as high as forty pounds to the cubic foot.

The result of all this improvement is obvious; it no longer pays the Eastern dairyman to raise his own hay. He specializes in his department. Even with the additional cost of freight, it pays the New York dairyman to ship in his hay from the West.

CHAPTER XIV.

Special Machinery On and Off the Farm.

DRIVING THE HORSE OFF THE FARM.

AS considered so far, the tremendous increase of efficiency in farming has been due, almost entirely, to ingenious mechanism, and not to any new kind of power. The plow, the reaper, the mower, the hay-rakes and press, and the harvester, are mostly worked by horse power. It has been only on some of the big corporation farms of the West that steam proved practicable, that is, profitable.

Steam traction engines were formerly used, but steam engines are expensive, not only in first cost but in consumption of fuel.

WHAT THE AUTOMOBILE BROUGHT TO THE FARMER.

So now comes the gasoline-engine. Almost everybody who reads this can remember when there were no such things as automobiles, and they may still seem, to many, only the toys of the rich; but it is owing to the great demand for them, that the gasoline-engine has been developed and applied to other uses. It has been this same development of the gasoline engine that has made the aeroplane possible. And now the farmer is getting his benefit.

GASOLINE CAN TURN ITS HAND TO MANY USES.

At the present time, the agricultural traction-engine is in the limelight. It is now becoming possible for the farmer who owns only two or three hundred acres to apply power to his machinery. An engine is being manufactured and sold which can be manipulated by one man. With it the farmer can attach it to his implements and, single handed, plow, sow and harrow a ten-acre field in one day, at a cost of about forty cents an acre. This is equal to the work of ten men with twenty horses. With the same engine he may saw his wood, pump his water, thresh his grain and haul it to market in a string of wagons.

FINDING A BETTER USE FOR ALCOHOL THAN DRINKING IT.

But while the gasoline engine was becoming cheaper, the cost of gasoline was rising, for scientists declared that the source of its supply would soon dry up. Now that difficulty is being solved. All over the world, agricultural experts are experimenting in the manufacture of alcohol. At present alcohol is more expensive than gasoline, but its price is constantly falling. It is believed that alcohol will not only become cheaper than gasoline, but that a simple machine will soon be perfected with which the farmer may distil his own alcohol at an infinitesimal cost, using for the purpose potatoes or other vegetables which he can raise on his own land. He will then himself control his supply of traction-engine fuel.

Herein lies a great possible revolution. The gasoline-engine is already suited to the use of alcohol as a fuel. When that fuel becomes very cheap, all implements will adapt themselves to an alcohol-engine that will be within the reach of every farmer. This will mean that the last of the farm drudges have been emancipated, and with them will go the horse.

WHAT HAPPENS TO GRAIN WHEN IT LEAVES THE FARM.

The process of reducing grain to flour is probably as old as the use of the plow. It may be even older. When men were still living on wild grains and acorns, they would pound them into powder between two flat stones. Some of the North American Indians, who are still in the stage of development where agriculture is unknown, employ such methods.

From the pounding-stones came the mortar and pestle. Even this improved implement is so old that it is found among the remains of the early Swiss lake-dwellers, who lived so long ago that there is no written record of their existence. There are places in Ireland also where artificial hollows appear in the rocks, so shaped that it is obvious they were used as mortars in which to pound grain.

A PICTURESQUE PROCESS PRAISED BY POETS.

The first genuine mills are supposed to have come into use in Italy about two hundred years before Christ, and the same kind of mill is still in use among the peasants of unprogressive countries. Two round stones, like grindstones with holes through their centers, are placed one on top of the other. The bottom

1. Basuto women grinding corn before a native dwelling.
2. Arab women grinding corn, their chief means of subsistence.

stone is stationary, but the upper stone revolves. The grain is poured into the hole in the middle of the upper stone, beside the shaft which turns it. Dropping down, it is ground between the two stone surfaces in which sharp grooves are cut, leading from the center to the edges. As the grain is ground it works its way along these grooves and finally, as flour, drops over the edges, into a hopper beneath the stones. From the hopper the flour passes into the bolting screens, made of coarsely woven cloth, which separate the bran, the flaked husks of the grain, from the fine flour.

At first the stones were small, because they had to be turned by hand, but, when water-power was applied, they were sometimes made six feet in diameter. We are familiar, through pictures, with the picturesque old millwheel driven by the millrace. The shaft from this huge wheel turns the upper millstone inside. Windmills were also used as the motor-power in those parts of the country where water was not available. We associate Holland with windmills; that is because, being a flat country, there are no streams with fall enough to turn the millwheels.

When grain had to be harvested by hand, the old-fashicned millstones were quite good enough. But when the reaper sent the grain into the granaries in great floods, the millers began looking about for more efficient machinery, and they found that the inventors had it ready—on paper.

A PROCESS NOT POETICAL BUT PRACTICAL.

About 1840 a Hungarian nobleman, considered eccentric, had built a flour mill in Budapest which used steel rollers instead of millstones. The rollers were designed by a Swiss mechanic, named Sulzberger. Nobody, at that time, took much notice of these queer people. But when we began flooding Europe with our machine-cut wheat, the steel-rollers were suddenly brought to the front and examined. And it was a

Frenchman, La Croix, who, shortly after the Civil War, introduced the Hungarian machinery into this country. He built a modern steel-roller mill in Minneapolis, and founded the greatest flour milling industry in the world.

THE WHEAT GRAIN AS BERRIES.

To understand the principle of steel-roller milling, we must first examine the wheat berry—for it is a berry. The outer covering, the husk, consists of three brown coats. Inside is the white, floury part, called the endosperm. Throughout its starchy texture runs a network of fiber. This is the gluten, the most important part of the berry, for it is that which makes the flour rise when the liquid and the yeast are applied to it. Finally, in the center, comes the germ, an oily kernel which must be eliminated, since it injures the keeping quality of the flour by turning it rancid. The perfect mill, then, must peel off the husks in flakes and grind the endosperm into flour without crushing the fatty germ. The husks are then separated by sifting, technically called bolting.

ROLLERS THAT DO NOT ROLL.

The rollers, therefore, grind; they do not really roll. Each roller is about five feet long and about nine inches in diameter. The surface of each is cut with spiral grooves from end to end, from ten to twenty grooves to the inch. Two rollers are set against each other, but, as one turns much faster than the other, the grains are ground between the grooves of each roller. While the rollers do not touch, they are so close together that, if a piece of ordinary paper were passed between them, it would be flattened into tissue paper.

In the old-fashioned mill the grain was thrown in as it was received, mixed with straw and with other kinds of seeds and dirt, or soil, clinging to the berry. Naturally, the flour was of an inferior quality, no matter how fine it might be ground. In a modern mill a complicated set of machinery separates the grain from all this undesirable foreign matter. It is, in fact, one huge mechanism which requires only to be oiled and regulated; not once does the grain or the flour touch a human hand.

THE GRAVITY ROAD THAT GRAIN GOES OVER.

An endless chain of scoops dips into the cars that bring the grain to the mill, lifting it to the top of the building. After that, the grain moves through all the different processes by gravity, unless it is again lifted by scoops. It is first dumped into a receptacle attached to a scale, and, when a certain definite weight has been reached, the weight is registered more carefully and accurately than any weighing clerk could possibly do it.

Now begins the cleaning process. The grain falls into the sieves. The first sieve is just coarse enough to allow the grain to go through, leaving behind all the straw or other matter which is larger than the grain. Then it passes over a screen too fine for a wheat kernel to get through, but all the smaller dirt is here eliminated; dust, loose soil, and the seeds of weeds. From this screen the grain travels over big, magnetized iron plates, to which cling nails, bits of wire or other metal, which might cause serious injury to the machinery.

After being cleaned, the grain is scoured. The scouring-machinery consists of long tubes made of fine, metal screening, inside of which stiff brushes revolve on spindles, violently agitating and scouring the grains against the screen sides of the tubes. Through these tubes and through the sieves passes a blast of air, blowing aside the straw, dust, and chaff. During all this process, the grains must not be too violently treated, otherwise the husks are broken and cannot be peeled off by the rollers.

Next, the grain is warmed in ovens. This is done to render the husks susceptible to moisture, for the grain is next passed through water, not only to wash it, but to render it tough, in order that the husks may come off later in larger flakes. The grain runs into big tubs in which the water swirls it about, finally washing it up into a receiver, which conveys it into the driers.

The driers are double, revolving cylinders, something like a coffee roaster. This process is just as delicate as the roasting of coffee, too, for the berries must retain a certain fixed percentage of moisture; neither more nor less will do. Then begins what is called the reducing process—the grinding and the bolting.

Usually there are five sets of rollers, each set grinding a degree finer than the preceding one. The work of the first set is to split the grains and loosen the husks, without producing any flour. Between each set the broken grain passes over the bolting cloth, the finer portions dropping through. A blast of air whirls aside the bran, the flaked husks, into bins. The germs, which are too oily to be ground into a powder, are caught in the last bolting cloth, whose texture is the finest of all; consequently, the flour which is sifted through it is of the finest and best quality. Flour is, or should be, graded according to the texture of the bolting cloth it has passed through.

From the bins under the bolting cloths the flour is carried into chutes which empty it into sacks. These are closed and sewn together by machinery, and so the flour is ready to be loaded into the cars that are to carry it to market. It represents seventy-five per cent of the whole wheat. The remaining twenty-five per cent. is the bran, which is sold as cattle feed.

Graham flour is wheat flour, except that it has not been bolted. Whole-wheat flour has had only a part of the bran removed. Gluten flour has had the starchy granules of the endosperm eliminated.

Such is the machinery that makes not only wheat into flour, but, with very slight modifications, the other cereals as well. The one exception is corn meal, which is still made by the millstone process, only in grinding corn meal, both stones revolve, each in an opposite direction.

THINGS TO EAT ARE OUR GREATEST INDUSTRIES.

In this country the flour milling industry, estimated by the net value of its products, is second in importance. Meat comes first; steel third. Here again we see graphic results of the reaper's work.

CHAPTER XV.

Modern Dairy Methods.

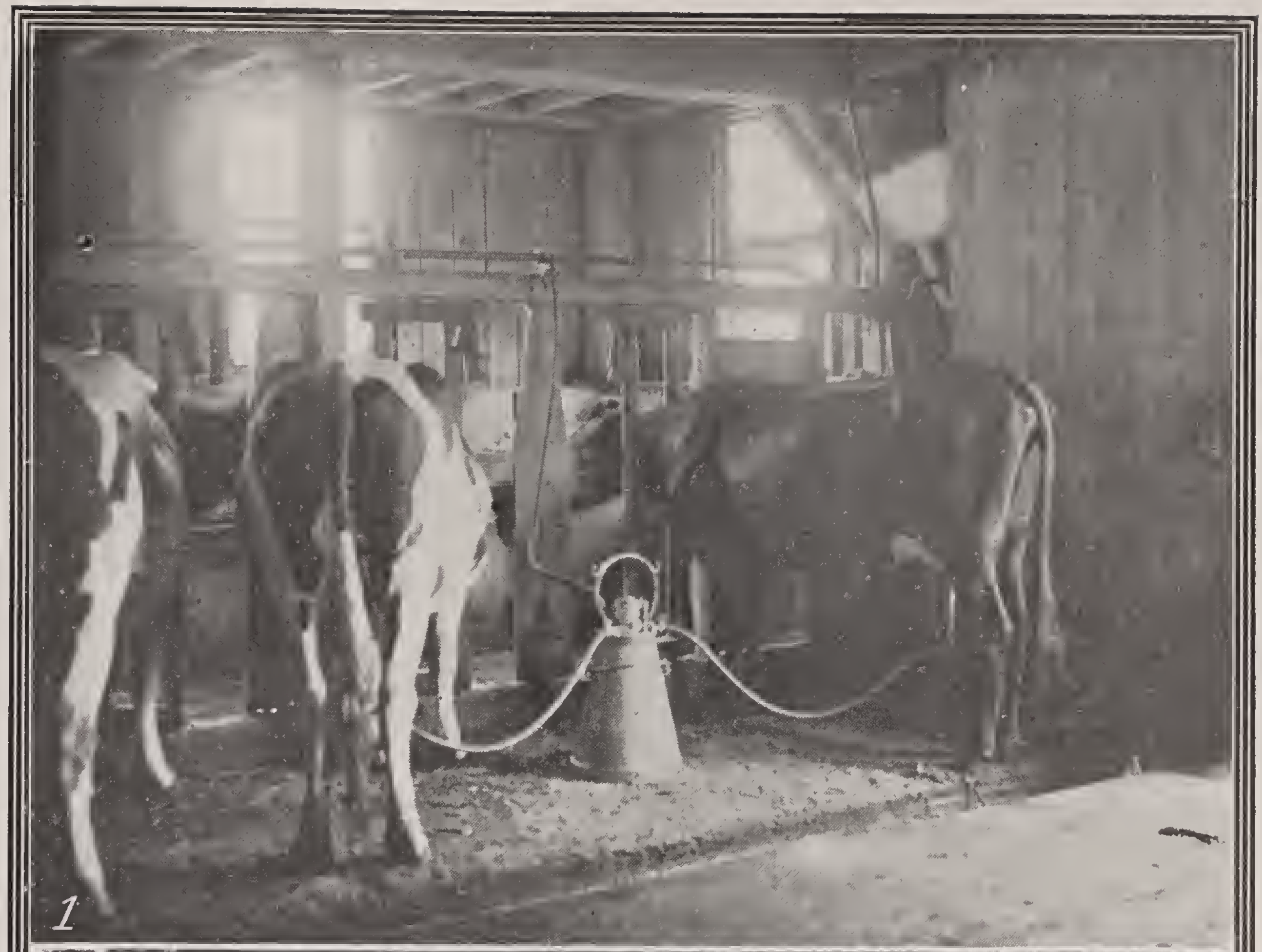
THE FIRST AND BEST OF FOOD.

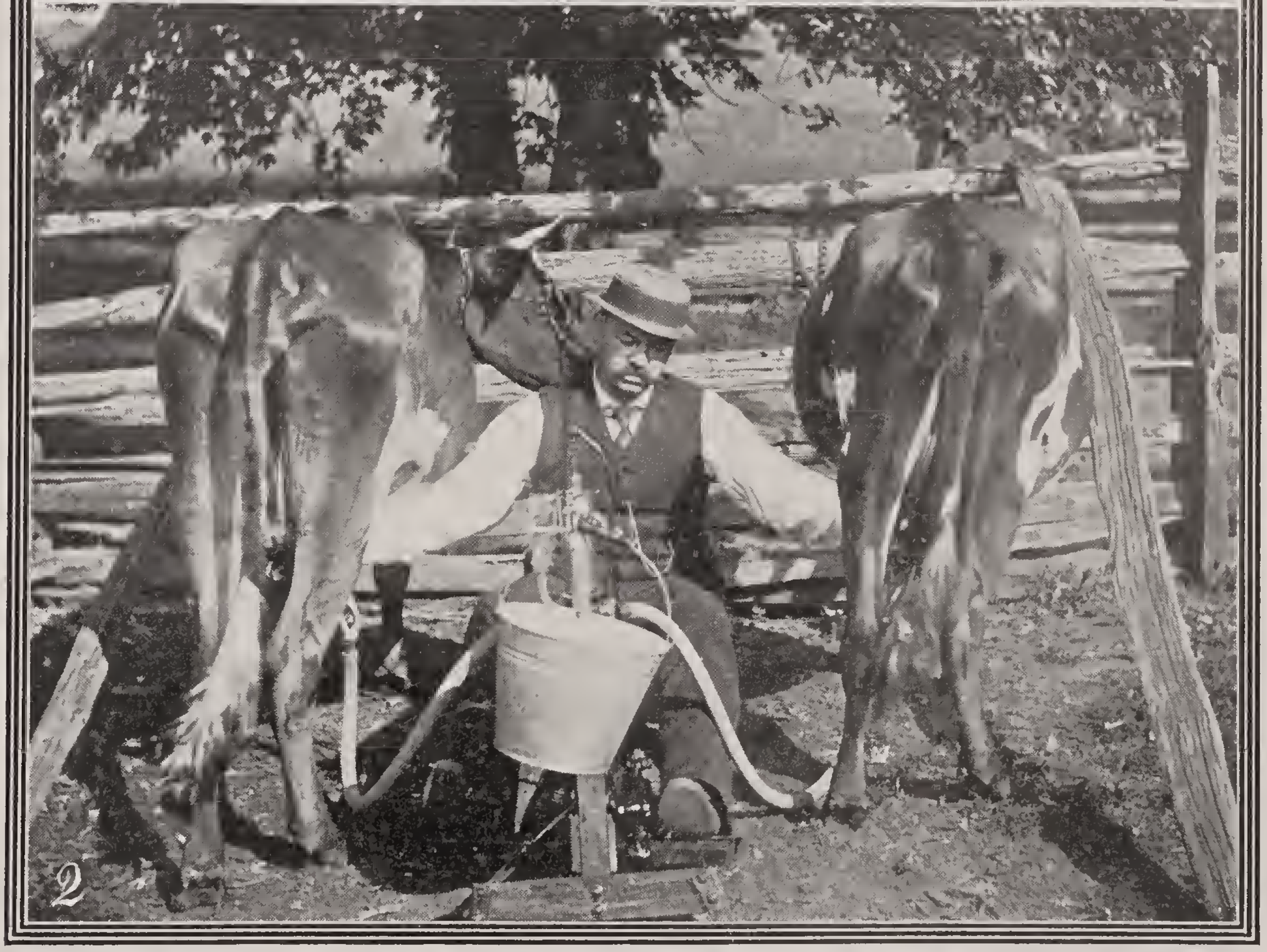
THE very first meal of the earliest of early inhabitants of the world was milk! And milk of one kind or another, with the various foods made directly from it—butter, buttermilk, cream, skim milk, cheeses of all kinds—have remained favorite articles of food ever since. While goat's milk is used for certain cheeses, and occasionally for cooking, it is upon cows that we depend for practically all the milk, butter, and cheese that the civilized world eats. And as milk from a healthy cow is, naturally, one of the purest of foods, so it is one that, more readily, and quickly than almost any other, spoils and becomes injurious to health. Thus, the health of cows, their housing, and their care, have become a science, in order that the food they give us to eat may be really clean, and pure, and fit for human food.

WHAT THE PRETTY DAIRY MAID FROM A FAR-OFF TIME WOULDN'T FIND.

The dairy maid of a few decades ago had learned much of milk, of cream, of butter, and of cheese, but the methods she employed have been so improved and changed that it is doubtful, could she be magically put in a modern dairy, if she would recognize it as such or know what was going on about her. Instead of the milking-stool and bare armed girls drawing milk from cows, she might find a set of pipes running from a pump to the cow's udder, extracting the milk by suction. Instead of the old-fashioned, barrel-like cylinder in which she worked, up and down, painfully and with effort, though undoubtedly with grace and picturesque effect, a long wooden handle ending in a dasher or disk, she would see whirling tub-like affairs, the modern rotary churn. Instead of long rows of shallow pans, set to cool in the ''spring house'' that the cream might rise from the milk, she would find a peculiar mechanism into which milk was poured, and out of which ran thick sweet cream, from one spout, and thin skim milk from another. When she came to the cheese rooms, she would find little tablets, or a fluid in a bottle, prepared and ready for use as the ''rennet'' which curdles the milk, instead of having to prepare her own. She would find great mechanical presses to compress the cheeses, machines to cut and stamp and pack them, instead of the lines of girls who, in olden days, ''patted up'' the raw cheese by hand.

She would see the butter taken from the great lines of power churns, ''worked'' by machinery, perhaps, instead of human hands, and, when finished, she would, perhaps to her dismay, find that no efforts on her part could produce so even a grade of such wholly





1. A Mechanical Milker worked by Water or other Power.
2. A Mechanical Milker worked by Foot Power.

pure butter, so regularly and so constantly, as can these whirling tubs and other mechanical devices that make solid foods out of liquid milk.

WHAT THE SAME DAIRY MAID WOULD FIND.

In fact, about all she would find that she could recognize would be the cow, and even Bossy, placidly chewing her cud, as she and her ancestors have done for ages past, would have a sleek and well fed, well cared-for look, which would surely be strange to the milk-maid from a far-off time.

A MACHINE THAT OUSTS BOTH CALF AND MAID.

But not in every dairy would she find the milking-machine. It is not, as yet, so unqualified a success as to be universally adopted. The problem of making a successful milking-machine is much harder than it seems. In the first place, no machine has the effect on a cow that her calf has; she misses in it the feeling of an animal near her. Generations have accustomed the cow to human hand-milking, but any milker will tell you that the cow which refuses to "give down" her maximum amount of milk to hand, will give it to her calf. Again, a milking-machine must fit different cows, whose udders and teats vary greatly in size and shape. A calf's mouth will fit any—a milking machine is not so adaptable. Still further, the machine must not irritate the cow, and here the cow's disposition comes into play; some animals take kindly to the affair of rubber and tubes; others will have none of it.

The milking-machine is simple enough in construction and principle, consisting of some form of air pump, designed to give intermittent suction, or "pulsations," which will correspond to the stripping motion of the hand in hand-milking, or the mouth suction of the calf in feeding. The suction is applied to the teats through rubber tubes, ending in rubber cups which are adjustable to the teats.

But although the machine has not been universally adopted, in some cases it has been found that, given intelligent care and handling and with attention to the comfort of the cows, the use of the machine increases slightly the yield of milk from the cow, and decreases the time of milking. For one machine can milk two or more cows at the same time, and one attendant can care for, adjust and manipulate several milking machines at once, thus resulting in great labor-saving. Perhaps the very greatest advantage of all, however, in the milking-machine, is cleanliness. Granting that the machine itself be absolutely clean and the cow's udder and teats washed before milking, there is no possible source of contamination of the milk in milking, since it goes through closed pipes to a closed vessel and is not touched in the process, by human hands—which may or may not be clean.

DISENTANGLING MILK FROM CREAM.

Setting milk in pans to separate the cream, is a method so old that its origin is lost in the mists which hide antiquity from our eyes. Butter-fat is lighter than the water and the other component parts of the milk. Let milk alone, and it will separate into two parts—the cream and the skim milk. But the process requires some little time, and then to separate the two strata from each other is a nice process, and, be the "skimmer" never so skillful, some of the cream is bound to be mixed with the milk and lost, and some of the milk is bound to be dipped up with the cream, making it less rich.

So the mechanical cream-separator was devised, a machine which separates the two, cream and milk, from each other in a different way from "setting" and on a different principle. If a stone or a weight is attached to a string and swung about the head, it will fly outward, making the string tight. The faster the weight is swung, the tighter will the string get, and the more nearly horizontal will the plane in which it revolves become. The force which holds the string tight and horizontal and the stone out, is called centrifugal force, or the force which sends a weight away from the center about which it is revolved.

If, in a dish filled with water, a few stones are put and the dish be revolved rapidly, all the stones will fly to the outside rim of the dish and stay there. And that is what the cream-separator does. It revolves a dish of milk, rapidly, so that the heavy part of the milk flies to the outside and the lighter part of the milk stays near the center. Cream is lighter than the fluid part of milk. Therefore, in a cream-separator, when the bowl is revolved, the liquid part of the milk flies to the outside, the butter-fat stays nearer the center. If, now, a constant source of supply for milk is provided for running milk into the bowl, and two spouts at different places to take out, one the skim milk, the other the cream, the machine will work away and separate the cream from the skim milk as fast as it is poured in. Of course, the rate of separation is controlled by various factors—the temperature of the milk, the speed of revolution, the rapidity with which milk is fed to the machine, etc., etc., but all these things are factors in a problem which is thoroughly understood, so that in the modern creamery, where power separators are employed, the butter and cream makers know, to a hair, just how fast the separator must revolve, at just what temperature the milk should be, and just how much milk must run into the separator every minute.

Most wonderful of all, perhaps, to that mythical dairy-maid of the last century who is visiting the modern creamery, would be to find on the cream-separator a screw, or adjustment, by which the attendant can regulate exactly the amount of cream that shall come out of the milk, and decide just how rich his cream or how thin his skim milk should be. Yet this, too, is very simple. It is clear that if there were but one outlet for the cream and milk together, the machine could not work; milk would be poured in, and nothing but milk come out. Putting two outlets, one near the center, the other near the edge of the bowl, makes the separated cream and milk come out separately and into different containers. If, therefore, a means be provided for making one opening smaller or larger, or of moving the point at which one of the outlet-pipes takes its supply from within the whirling bowl, then, obviously, the richness or poorness of the milk and cream can be controlled. So it is perfectly possible for a dairy manager to establish a cream standard up to which he will live, and deliver to his customers cream of just exactly that standard, winter and summer; always provided that the richness of the standard is not greater than the cows' milk can compass, in the poorest season—that is, in winter. In summer, when the milk is richer, the attendant on the machine changes the adjustment so that the cream is less rich than it could be; in winter, when the milk is poorer, the adjustment is again changed, so that all the richness in the milk goes into the cream.

Cream-separators are now made, not only in large sizes and for power-use, but in small sizes, worked by hand, so that many farmers who formerly had to depend either upon "setting" their milk to get the cream, or had to go to the trouble of shipping their milk to a creamery to get it separated and having the skim milk shipped back again, can now do on a small scale, on the farm, what the big creamery does in its big separating plant. These small sized separators have greatly improved the yield of cream from milk for the farmer, and have assured him pure skim milk to feed to his pigs, if that is what he wants to do with it; and, when intelligently handled and with care for cleanliness and purity, they have enabled him to be sure of purer and better milk and cream than was ever before possible. The little machine, with its handles, whirling bowl, and spouts, is not so picturesque as a whitewashed spring-house, long rows of pans of milk, and a bare-armed, fresh-faced country girl skimming, but it is much more practical and produces more cream and butter than the old way did.

A CHURN WITHOUT A MISTRESS.

When it comes to butter making, too, the separator has another improvement to show over old methods. In ''settling'' new milk to get cream, it is generally customary to strain it through cloth. No matter how much attention be devoted to these cloths, it is hardly conceivable that some of them do not sometimes get overlooked or neglected, and thus become foul—which a straining cloth very speedily does. In the use of the separator, previous straining of the milk is unnecessary, the separator getting rid of all dirt and sediment, without any trouble whatever, provided, of course, that the milk is not absolutely filthy with sticks and refuse.

Practically all the butter made today is made from sour cream, sweet cream butter being tasteless to most people. But, in spite of this fact, modern methods have resulted in a curious condition of things—the great desire on the part of the dairyman to keep his cream as sweet and pure as he can, up to the time of butter making. He is no longer careless of it, ''because it has got to sour anyway for good butter.'' He keeps it at a low temperature, separates it as speedily as he can, keeps it covered and free from contamination, until such time as he is ready to have it sour for butter. The reason is simple. Cream which sours in the rising or in waiting for churning, will do so, more likely than not, from bacteria which cause souring from putrefaction, gassy fermentation, and other undesirable changes. In other words, there is a desirable souring, which produces butter of good flavor, and undesirable souring, caused by the wrong kind of bacteria. Cleanliness, coolness, and care keep the cream sweet until it is ready to sour, when it is made to sour by adding to it a "starter," which is usually nothing but properly soured milk, either whole or skimmed.

When the cream is properly soured, it is ready for the churn. And the churn, simple though it be in principle, has taxed the ingenuity of inventors since the earliest commercializing of the dairy, and many attempts have been made to find a "one minute" churn —a machine which would produce butter in the smallest period of time.

Butter-making usually takes from thirty to forty-five minutes for the butter to "come," but if "the cream is cranky," it may not "come" for a much longer period. And as time is money, the inventor figures that by saving time, he can save profit. Hence the numberless patent dashers, churns, cups, whirling devices, paddles, and other mechanical things, all "warranted to make butter in ten minutes."

But the inventor has failed, so far, to do much to improve the old-fashioned churn, although he has amplified it, and enlarged it, and driven it by power. The churn used in nearly all large creameries today is a modification of the well known barrel churn, in which the container revolves and drops the creamy contents from dasher to dasher, the falling of the cream itself doing most of the churning. Nor can one make butter faster by turning the churn beyond a certain speed, for, as soon as the centrifugal force becomes strong enough it holds all the cream against the sides of the churn, which then whirls around with cream and churn as one solid object, and doesn't "churn" at all.

The principle of the churn is simple enough. The fat in the cream exists in the form of minute globules, each separate from its fellows. If two or more of these globules can be smacked smartly against each other, they will adhere to one another. If two of these united globules strike each other, all four will cling together, and so on. Churning or agitating the cream with the right amount of force flings these little flat globules against one another, and they stick together in little lumps. It takes some time for the lumps to reach a size that can be seen by the naked eye, but, as soon as they do, they speedily form larger and larger lumps; and, when these lumps are about the size of beans, the churning is stopped, the buttermilk drawn off, and the mass of butter-particles is ready for further treatment.

When butter refuses to "come," it may be owing to a wrong temperature of the cream, or a wrong ferment, or several other causes. But "the cream is cranky" if the farmer's wife has given way to a scientific investigation of the subject, and now, when the butter "won't come" in a creamery, they usually know pretty well why it won't, and generally can prevent such an occurrence beforehand by scientific tests of the cream before and after souring.

In great creameries, the subsequent operations of butter making proceed by machinery—that is, the "working" of the butter, in which the many little lumps are "worked" or pressed into one big, smooth, homogeneous mass, without being made sticky or greasy or soft; "washing," in which the buttermilk is taken out of the butter; and "salting," in which salt is put in. But these operations are simply huge editions of the older hand-operations. "Working" is still done by rollers rolling out the mass of butter, folding it over, and rerolling; and salting is still accomplished by rolling salt into the mass, or mixing it with the butter-lumps in the churn after the milk has been washed away and the water has been drained.

THE MYTHICAL DAIRY MAID AGAIN.

Yet, for all this, the process of making butter is chemically the same as it was a thousand years ago, only the means of carrying out the processes have been made highly scientific. And, although we miss, in the loss of the little home-dairy and its pretty maid, much that was pleasant to look at, even she, coming back from her ancient home to a modern creamery, could not help but admit that the modern pneumatic cow-milker, the modern cream-separators and the modern revolving churn, produce better results, cleaner results, and more results, from a given quantity of milk and cream than she could do, even with all her skill.

CHAPTER XVI.

The Meat Industry.

A TRAIL OF BLOOD THROUGH HISTORY.

IN no one department of human activity, supervised and controlled by science and knowledge, have greater strides been made, within recent years, than in the preparation and care of those foods which we obtain from the bodies of animals.

Butchering, or the preparation of animals for food, is the oldest known trade of man, since, from the very beginning, he had to eat, even before he built himself houses, or had the first glimmerings of a civilization. And, for centuries, the essentials of the trade remained the same. Hogs, pigs, sheep, lambs, cattle, calves and goats, the animals best suited for the food of man, were slaughtered and prepared for food in 1800 very much as they were in the year One—for that matter, as they were killed and prepared as far back as history goes. Even to-day, when modern methods, machine work, and all the improvements which sanitary and humanitarian science can suggest, have remodeled the killing and packing houses of the world, the "home" butcher-shop still exists, and "home killed and dressed" is still a point of pride among certain people who have yet to realize the immense strides made in this necessary trade.

To many the subject may seem disagreeable, involving, as it does, a description of the means of taking life and the preparation of a body which, the life gone, is but uncooked food of a bloody and repulsive appearance. But from the very beginning of butchery, man has found that it paid to be merciful, that the swiftest killing, with the least pain and fright involved, produced the best meat. This is particularly true today, not only in regard to the actual butchery, but to the previous care of the animal. The time when thousands of beeves could be confined for long periods in cattle cars, without food and water, "because they are going to be killed, anyway," has passed. State and national laws protect the dumb animals and make it a punishable offense to transport animals in either unsanitary or cruel vehicles, or to keep them, beyond certain prescribed periods of time, without food and water.

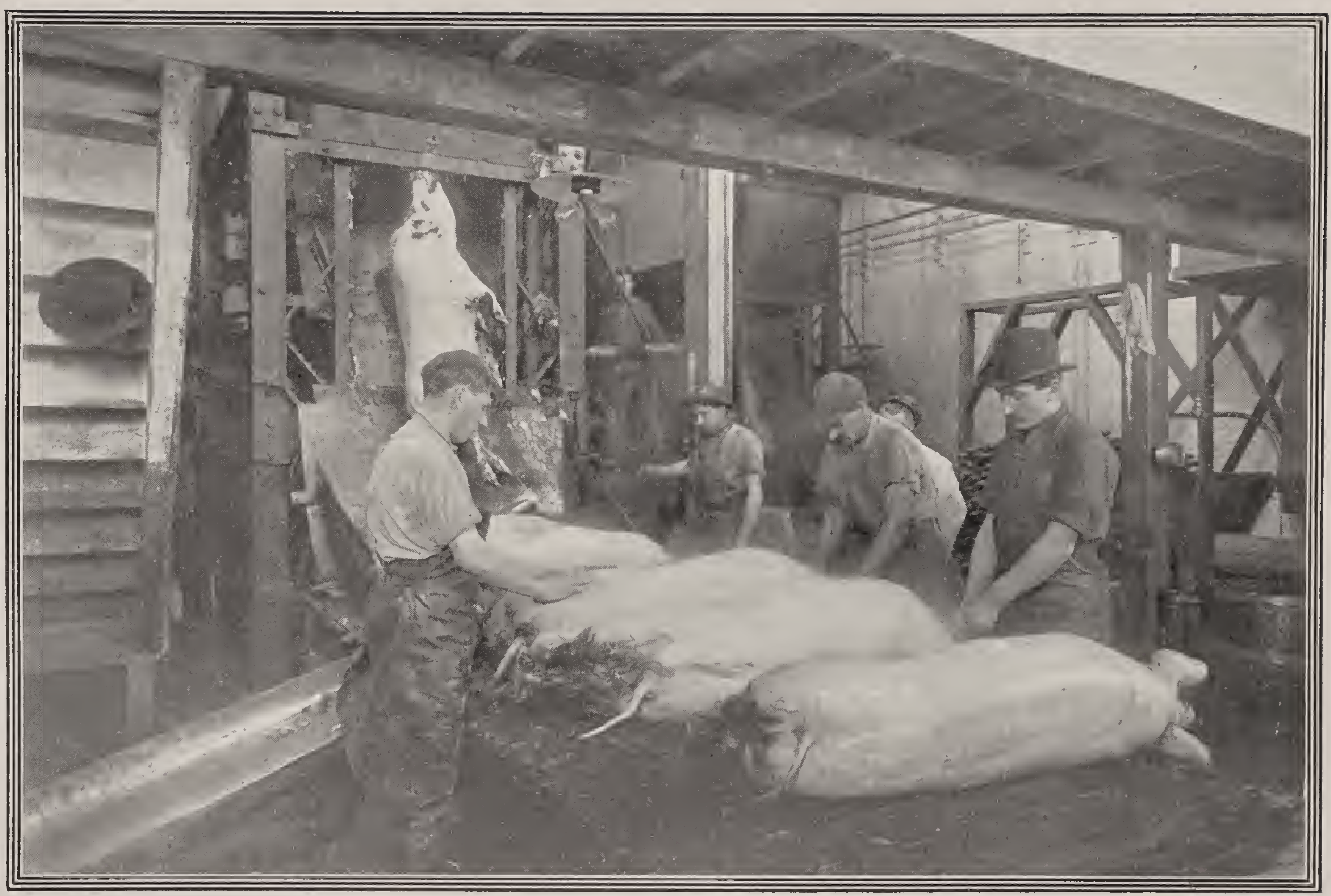
HUMANE KILLING VERSUS BUTCHERY.

In the old days—and even yet in the little "home" butcher shop—sheep and pigs were killed with a stroke of the knife which, if skilful, severed an artery and let them bleed to death. But that practical industrial science, which is forever striving to save a minute, to add a mite to the efficiency of any mechanical operation, has improved even this time-worn method; and, though the knife is still the means of taking the life of animals, no such bloody and terrible scenes as are witnessed in the farmers' killing-pens, where the tools of the trade are wielded by unskilful hands, are seen in modern packing houses. Here machinery and great skill dispose of the animals in rapid succession, without any undue fright or pain.

In a "home butchery," the butcher cuts the animal's throat and he bleeds to death on the ground. The carcass is then cut up, also on the ground, with knives, and the various parts hung up, pending storage or sale. In a packing house, no part of an animal's body comes in contact with anything but clean hands and steel after the life has left it. The beeves are first confined in inclosures called "knocking pens," above which, on a platform, is the "knocker" who first stuns the animals with a sure blow from a pole axe. Instead of dragging the body to the scene of the next operation, the side of the pen drops down, the floor tilts, and the animal rolls out on platforms called "beds," a short distance below. Here a shackle is attached to one of the hind legs and the beef hoisted up so that it hangs, head downward, from a trolley working on a rail. A butcher called a "sticker" severs the blood vessels in the neck, so that the animal bleeds painlessly until he dies, the blood being caught in a receptacle and saved, first for examination and then for use in the preparation of certain food products.

A SWIFT TROLLEY RIDE TO THE CHILL ROOM.

The body now moves forward on the trolley and a rapid succession of operations takes place, each by an expert butcher. "Leggers" remove the hind legs at the hock and the forelegs at the knee; a "sider" partially skins the animal; a "caul puller" slits the body and removes the fat from the abdomen; another butcher saws through the sternum; another does more skinning; another skinner completes the operation entirely, leaving the hide attached only at the neck; a



ONE STEP IN THE PROCESS OF PREPARING MEAT FOR MARKET.—These hogs are being scraped by hand, having already been treated by machinery.

"gutter" removes the internal organs; a "rump sawer" splits the carcass, which operation is completed by the "splitter;" a "hide dropper" separates the hide from the neck; another butcher severs the vertebrae; and finally trimmers remove the spinal cord, pump the blood from the legs by rapidly working them, and trim up the meat.

The next process is washing with a stream of hot water, which is either squirted on the meat from a hose, or applied with an ingenious combination of hose and brush, that scrub and wash at the same time. The meat is wiped dry with clean towels, and, after passing an inspector who marks the carcass in five places, usually the loin, rib, chuck, plate and round, goes to the "chill room" where it is stored for a period of forty-eight hours at a temperature of 36 degrees F. It is very necessary that the meat be thoroughly chilled as soon as possible after killing, for only in this way can decay be arrested and the meat properly stored or shipped. To ship unchilled meat would be to expose the purchasers to disease and to the eating of meat unfit for food, whereas, once the meat is thoroughly chilled, it can be shipped, in refrigerating cars, for long distances and kept fresh an almost indefinite time. Refrigeration is thus one of the most scientific improvements which the nineteenth century gave to the meat industry.

This process of swift and painless butchery, in which each operation is performed by a skilled butcher, working only on one part of the animal, is distinctly an American innovation, and provides not only mercy to the animal but great speed, so that the minimum of time elapses between the last living breath of the animal, and its storage in the chill room as food.

Substantially the same processes are used for the killing of calves, sheep, and goats, but the killing and preparation of hogs for food is somewhat different.

In many of the larger packing houses, from three to five hundred hogs can be killed and dressed in an hour; in such a plant as this, the process is as follows:

A PORKER ON HIS WAY TO PORK.

The hogs, previously inspected to cull out those that appear unhealthy, are herded in a group in a pen, at one side of which is a huge wheel, bearing hooks upon its rim. Workmen attach these hooks, by means of chains, to the hind legs of the hogs, and as the wheel revolves, the animal is raised from the floor and carried to an inclined rail upon which it automatically slides. The animal is thus conveyed to the ''sticker,'' who, with one swift stroke, severs the neck blood-vessels, when the animal bleeds to death. It has been found that hogs, having extremely tough skulls, suffer less and make better meat, if thus killed by bleeding, than if first stunned with the pole axe. When life is extinct, the body is dropped into a huge vat of boiling water, through which it is passed by workmen, who pole it along from one end to the other. Huge, finger-shaped hooks grasp the body and carry it to an automatic scraping machine, for removing, swiftly and expeditiously, such of the bristles as have been loosened by the hot water treatment, just as scalding loosens the feathers of a fowl for picking. When this machine has finished its work, it drops the body onto a moving platform, which carries it to the first butcher who nearly, but not quite, severs the head. Beside the butcher stands a Government inspector, who looks closely at the exposed glands of the neck, to detect tuberculosis, if any be present. If, as is usually the case, the hog is healthy, the body is passed along for further work. Gambrel sticks are affixed to the legs, holding them fast, and the body is hung on a trolley, to be further scraped by hand, and divested of the few bristles left by the machine. The body is then split, cleaned, and the other butchering operations gone through with, as described for cattle, the meat finally ending, as before, in the cooling room.

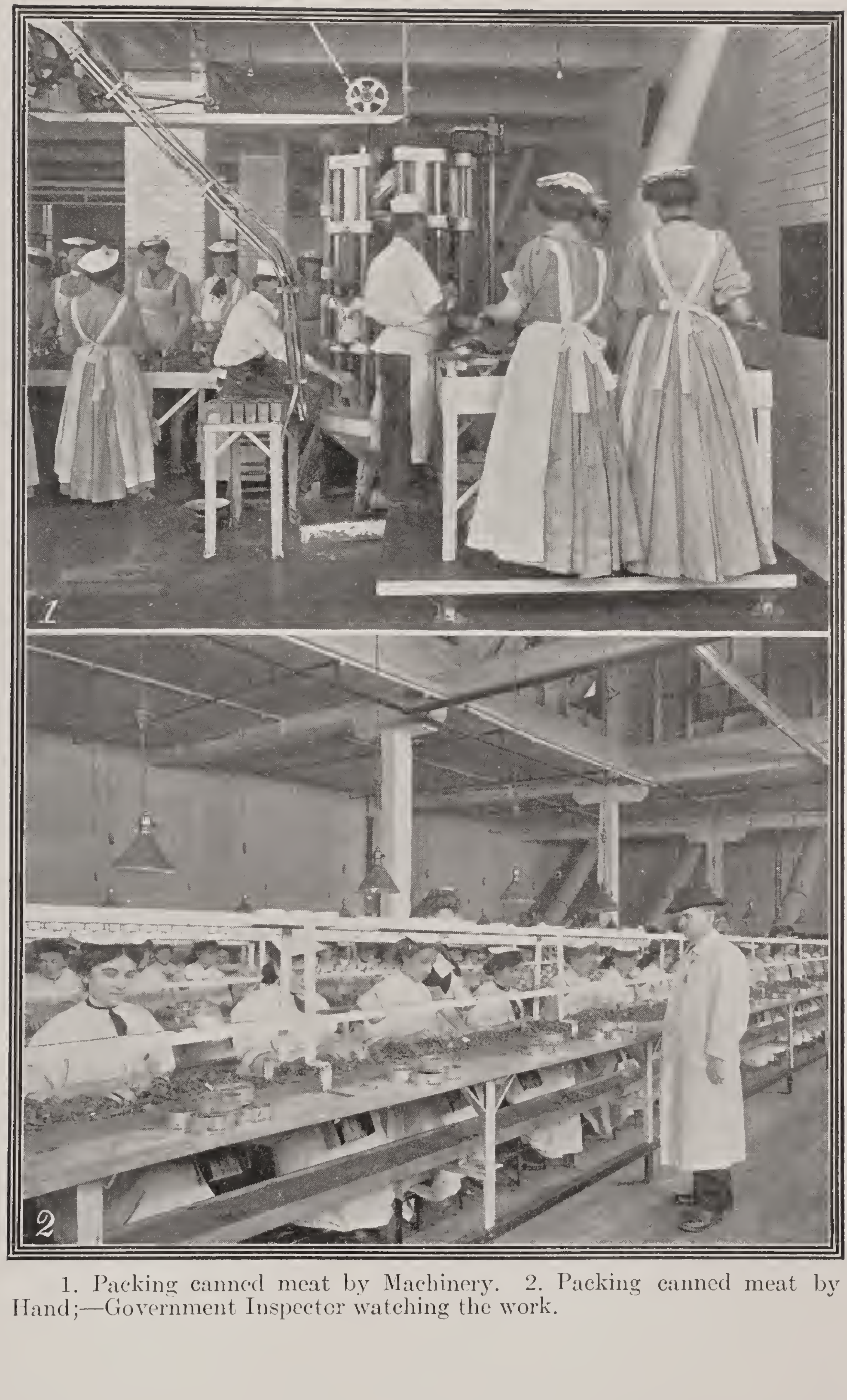
ANIMAL DEATH NO LONGER A MENACE TO HUMAN LIFE.

One of the modern wonders of the meat industry is the revolution wrought in butchering-places by proper laws and the demands of sanitary science. The prevention of disease is so much easier than its cure, that it has been found to be a paying investment, even by the packing industries, which first fought all idea of Federal inspection, to provide clean premises for butchering-operations and permit rigid inspection of the cattle and hogs designed for eating.

In past times, a man's business was his own. If he wanted to kill hogs on a dirt floor and dress them on a wooden bench, black with the dried blood and offal of a hundred slaughterings, it was his own affair. We know better now—it is the people's affair, who eat the meat—the Government's affair, which is the people. So we have a Federal law, which prevents the shipment of meat, prepared by a wholesale firm or corporation, from one state to another, unless it is inspected by a Government inspector and pronounced fit for food. And the Agricultural Department will not supply inspectors unless the premises come up to Federal requirements; so, nowadays, a degree of cleanliness and sanitation is insisted upon which formerly would have been deemed unnecessary and foolish. Today, all rooms used in butchering processes must be well lighted and well ventilated. Walls and ceilings must be frequently cleaned and whitewashed and floors kept spotless. All utensils, knives, receptacles, trays, runways, everything that comes in contact with meat, must start each day clean. Clean clothing is insisted on, and inspection extends to the butchers and assistants, no tubercular person and no one with a communicable disease being eligible for employment. To such an extent is personal cleanliness insisted on that, in many modern establishments, manicure girls are employed to keep the hands of the workmen who handle food products, such as chipped beef, in a sanitarily clean condition.

Animals for food are inspected before being killed, and diseased ones rejected. The meat is again inspected after the animal is killed, and any even suspected of disease is held for further elaborate and careful examination. As soon as an inspector rejects or ''retains,'' as it is called, a body for further examination, all workmen who have touched that body and all tools used upon it, must be made clean by the use of a sterilizing solution, that no contamination may reach the next animal.

But the mere fact that something is found wrong with a sheep or hog does not necessarily mean that it is to be thrown away. Some animals are found so unhealthy that their bodies are consigned to a tank where they are reduced to a liquid unfit for food and used only for commercial purposes—the fat, of course, making an excellent grease, although not a food product. These ''tanks'' are really steam rooms, where the meat, subjected to live steam at a temperature of 240°F. for several hours, is reduced to fiber and running liquid, mostly fat. Other animals, however, may have a strictly localized abnormal condition, which in no way affects their value as healthy food, once this part is removed. Thus, an isolated tuberculosis nodule on the liver would not affect the body of the animal, and it would not be condemned—merely the liver would be condemned. An eminent medical authority makes the statement, ''Not any single animal used for food in any part of the world would, upon microscopic study, be shown to be absolutely free from all lesion or infection.''



1. Packing canned meat by Machinery. 2. Packing canned meat by Hand;—Government Inspector watching the work.

THE NEW ERA OF CANNING AND WHAT IT MEANS TO US.

This system of inspection, which the United States government has called into being, does not stop, as it formerly did, when the animal is killed and cut up. The "trimmings," formerly wasted, now become our potted meats, our sausages, our soups; and not only is every part of an animal's body now inspected, but all the organs of that body which are used for food.

The process of making canned meats is entirely different and distinct from the preparation of uncooked meat for market, and forms an industry in itself. Our ancestors knew little or nothing of canned food, and what they did know was not much of good. It is only in recent years that the prejudice against food so preserved has been removed, and rightly so, for it is only lately that canned food has been properly and healthfully prepared. The theory underlying all canned food is this: Remove all air from properly sterilized meat or vegetables, keep them in an absolutely clean and air-tight container, and they will preserve their chemical constitution unchanged for an indefinite period.

With this idea for a beginning, the great canning industries have come into being, where food, properly and tastefully cooked, is put into sterile cans filled to the rim, on which tops, also sterile, are soldered by machinery. The material in the can, when it cools, shrinks slightly; but the space left in the can is a vacuum, filled only with vapor of the fluid in the food, since the top has been so put on that it hermetically seals the contents of the can.

To avoid expensive machinery and troublesome operations, many canneries have been in the habit of using preservatives for their meat, which in themselves have proved unhealthy. Our Pure Food law now prescribes exactly what preservatives must not be used, and requires an honest labelling of the product, so that no one need eat a canned food with any chemical preserver included, unless he wishes.

The revolution worked in food products by the canning process can hardly be realized by a modern housekeeper without reference to the bill of fare before the era of canned goods. Not to mention the host of fresh vegetables now as available out of season as in season, the rich meaning of the fact is not, even yet, fully grasped that fruits, jellies, soups, oysters, relishes either bottled or canned, and all forms of meat, cooked and ready to serve, hot or cold, without preparation, can now be purchased almost everywhere, while formerly one had to take, with thankful spirit that he could get it at all, whatever the butcher or grocer happened to have in stock.

This strictly modern food idea has all been made possible by the introduction of inventions and machinery. If the meat were to be handled, cooked, and canned by hand, there would be neither profit nor health in the product. But the cannery uses a kitchen which, instead of the familiar room of stove and oilcloth-covered table, resembles, rather, an immaculate laboratory in which expert cooks, with thermometers and the finest of heating apparatus, prepare their dishes on a huge scale—hundreds of pounds, for instance, of minced ham being prepared in one batch. The prepared food never touches a human hand nor an unsterile vessel, and is fed into thousands of waiting cans by machinery, pressed down by machinery, capped and soldered by machinery, and again hauled thousands of miles throughout the world, also by machinery, so that in this modern age we almost eat by mechanism.

In spite of the speed at which a packing-house force and its machinery works, it can easily be seen that it may often be necessary to preserve raw materials for some time in stock before using them; so, since raw as well as cooked meat finds its way from packing-houses everywhere to remote portions of the country, a sanitary and strictly healthful method of transportation had to be devised to keep the meat fresh upon long journeys. Were it not for this method, there would be no fresh meat upon an ocean voyage, either; nor would restaurants or hotels be able to afford a complete *menu* of everything the market affords, since, if they could not preserve, they could not afford to buy, the dishes not often called for.

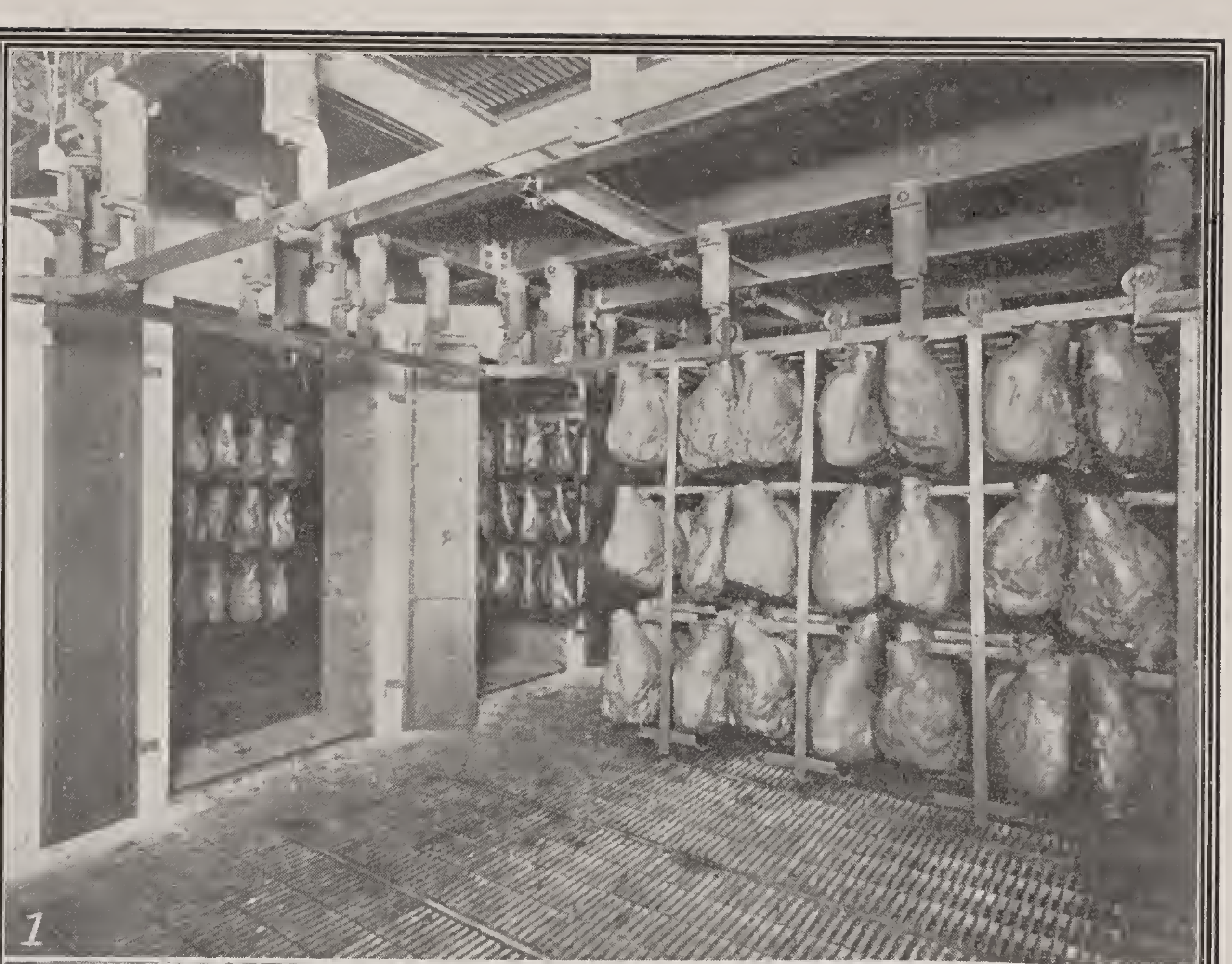
HOW REFRIGERATION, THAT ENRICHES OUR MENU, IS ACCOMPLISHED.

This method of preservation is found in the refrigerating plant and the refrigerating car, both adaptations of an old idea, but worked out in a most wonderful manner. Wherever ice is available, it is possible to make a room cold, but the amount of ice required, its bulk, the expense and loss on storage, would soon make such a means a prohibitive one, were it not for ice-making and refrigerating plants.

The principle of ice-making, which is the principle of the refrigerating plant also, is at once simple, beautiful, and marvelous. In one way, it is the reverse of a cooking plant. When a fire is lighted in a stove to cook food, heat is liberated from fuel, by means of a chemical change. Coal is merely stored-up sunlight; the latent heat, which combustion liberates from coal, was put into that coal by sunlight and chemistry —the wonderful dynamic of Nature's vast laboratory.

A refrigerating plant, instead of using the products of combustion to produce and convey heat, transforms the heat of a fire into steam, the steam into energy, and uses that energy to compress a gas, usually ammonia gas. It is a law of physics that, when gas is compressed, it gets hot; when it expands, it gets cool. This is another way of saying that, in any given volume of gas, there is a corresponding amount of heat; compress that volume of gas to less than its original bulk and the same amount of heat will be present but in a much smaller space; consequently, the gas, compressed, will be much higher in temperature than when expanded. The ammonia gas which the engines or compressors of a refrigerating or ice-making plant compress, thus gets very hot. In its compressed state, and while hot, it is cooled by being passed through pipes over which running water drips. The compressed gas is thus robbed of its heat, and comes to the temperature of the water dripping over the pipes. If, now, that compressed gas, at a normal temperature, be allowed to expand again to its normal bulk, it will drop in temperature, since what heat it has will become distributed through the greater bulk of its expanded state. Any cold body will absorb heat from the nearest source of supply. If the pipes in which the ammonia gas is allowed to expand, pass through the air of a room sealed against leakage of warm air from outside, they will draw heat from that air, thus cooling it; and the degree of cooling can be exactly controlled by the number of pipes, their surface, and the amount of compressed ammonia allowed to expand within them, very much as the heat of a steam heated room can be absolutely controlled by the size of the radiators and the amount of steam which passes through them. Here, then, is the refrigerating plant —a means for compressing gas, a means for cooling the compressed gas and robbing it of its heat, a means for expanding that cooled compressed gas and allowing it, in its turn, to rob the surrounding air of its heat. Of such construction are cold storage warehouses, cooling rooms in packing plants, and the refrigerators of hotels, restaurants, steamships, etc.

If it is desired to use the refrigerating plant for making ice, the pipes in which the ammonia expands pass through brine (salt and water, which will not freeze at the temperature at which water freezes), which, in turn, surrounds tanks full of fresh, clean



1. Hams hung in a Cold-storage Room.
2. Pressed Beef in Cold Storage.

water. The ammonia gas, expanding, chills the brine, and the brine, in its turn, absorbs heat, through the tanks, from the water within; then, when enough heat has been taken from the water to reduce the temperature below 32° F., the water freezes and a huge block of artificial ice results.

The refrigerating car is merely a traveling refrigerator, in which ice packed between the hollow walls keeps the contents of the car cold, so that meat, taken from the chill room of the packing plant, travels to its destination as safe from decay and chemical change as if it stayed in the refrigerating room at the packing house. Its use has not only made good meat and inexpensive meat possible at long distances from great meat killing and dressing plants, but has provided a market outlet for fruits and vegetables clear across the continent, where formerly the shipment of perishable vegetables and fruit was limited, in warm weather, to a distance which could be traveled in twenty-four hours.

IT IS SCIENCE THAT HAS MADE ALL THIS POSSIBLE.

Non-technical and unscientific readers are sometimes likely to think of chemistry, engineering, and biological, bacteriological, and microscopic studies, as entirely theoretical and of little practical value. In the meat industry, from the first killing to the last cooking, the whole marvelous process is based on a scientific precision and made possible in its present form only by a practical application of principles that were first demonstrated in the laboratory by the scientist. If today we eat fresh meat a month after it was cut from the newly butchered animal, or canned meat which has been months on the shelves, and find our food as good and pure as it can possibly be, it is because science and the practical side of engineering have stepped into the housekeepers' domain and given us sanitary food-preparation processes, humane and sanitary food-protection laws, and an artificial cold as effective in preserving raw food as is artificial heat effective in making, from raw material, dishes suitable for our tables.

CHAPTER XVII.

Poultry Incubators.

LITTLE FELLOWS NOT MOTHERLESS, BUT UNMOTHERED.

THE incubator is not a modern invention, although it was left for the experimenters of recent years to produce a scientific mechanical hen, which was as successful as the feathered bird in producing chickens from eggs. The Egyptians, long before the Christian Era, understood the simple principle of incubation, and some of their hatching-ovens have been unearthed by the archaeologists who have reconstructed for modern eyes the civilization of a dead-and-gone-past by digging deep beneath the surface of the earth and bringing to light the appliances and possessions of our long-forgotten forefathers.

Until within a perod of fifty years, however, the vast majority of eggs were hatched by hens, whose curious instinct to sit on their nests full of eggs for three weeks, save at feeding time, is one of the mysteries of that mother-love which in all the animal kingdoms works for the perpetuation of species. But science, far removed in idea from love and sentiment, reasoned that, whatever the cause which made the hen sit upon her eggs, all she actually did was to keep them warm. And experimenting confirmed the simple principle of incubation, which is, that a fertile egg, kept for the proper length of time at a certain temperature, under certain conditions of moisture and position, will be transformed, by an alchemy even science cannot understand, into a healthy chick, which, also cared for properly, will develop into as lively and useful a chicken as any which first saw light from beneath a mother-hen's feathered wings.

WHAT IS A COOP WITHOUT A MOTHER?

Incubators, therefore, are merely devices or machines, as they are called, which provide a place in which eggs may stay, surrounded by the proper kind of air, at the proper temperature, and with a means for taking care of the young and tender little chicks when they finally break their way out of their shells and give the first feeble ''cheep, cheep'' their first word to their new and untried world.

SCIENCE GIVING POINTERS TO THE MOTHER HEN.

As might be expected, science has improved upon the hen as a mother, as far as being a source of heat and a caretaker of the eggs is concerned. For there are many kinds of hens, and not all of them take their responsibilities seriously enough. Some too soon get tired of sitting and wander away from their nests for too long a time, and the poor little unborn chicks in the eggs, depending for life on warmth, die for the lack of it. Some hens insist on sitting in unhealthy places, with the result that the eggs hatch out poor chicks or only a small proportion of healthy chicks to a large number of eggs which should have hatched, but didn't. The hen, for all her mother-care of the eggs beneath her, not infrequently breaks some of them by incautious and, let us hope, unknowing carelessness with her feet.

The incubator does none of these things, if properly managed. But the incubator is not entirely automatic; it must be looked after and cared for by the human operator, with both knowledge and patience, else the conditions of hatching, which come naturally to the hen, will not be carried out in the machine, and the humiliating confession be made that the operator couldn't do as well as the hen could have done.

A HEN'S NEST THAT IS NOT A HEN'S NEST.

Incubators are almost invariably in the form of wooden inclosures or rooms, set upon legs, like a table, and having an internal arrangement by which the eggs are laid out upon a tray, with an air chamber above and, beneath, a space called the nursery, into which the newly hatched chickens drop and are cared for until it is time to remove them to the brooder. A lamp, or other source of heat, is provided to maintain the proper temperature, and a regulator, or thermostat of some sort, to keep this temperature where it should be. A thermometer forms part of the outfit, watching which, and making adjustments in the regulator and the lamp, at stated intervals, forms one of the most important duties of the attendant. Turning and cooling the eggs is another important duty, for, while the eggs must not be chilled, it has been found that a slight periodic cooling is necessary, simulating the cooling which the eggs hatched by a hen receive when she gets off her nest for food and drink.

WHAT SHOULD BE DONE AT THE HEN'S LUNCH HOUR.

Eggs under the hen get a certain amount of ventilation and a certain amount of moisture, and these conditions, too, must be copied by the machine. Generally it is found that the cooling and the ventilation are amply provided for in the five to ten minutes, every day, in which the eggs are turned. And the turning of the eggs is one of the improvements of science over the hen. Unquestionably, the hen does turn her eggs by motions of her body, but that she turns each egg, every day, is hardly to be believed. The necessity of turning the eggs is found in the fact that the contents of the egg, wonderfully changing into a chicken under the influence of heat upon the germ of life the Creator permitted to be placed within it, is inclined to settle to one side, and that unturned eggs not infrequently result in chickens being born deformed, or firmly attached to one side of the egg shell.

A SUBSTITUTE FOR DEWY FEATHERS.

Moisture for the eggs is supplied by a sponge, saturated with water, introduced into the hatching chamber, or by keeping the incubator in a room naturally damp enough; sometimes it is done by dampening the eggs very lightly, for it has been noted that a hen getting off her nest for food and exercise frequently returns to it with dew clinging to her feathers. Moisture in a certain proportion is necessary to hatching eggs, because egg shells are porous, and evaporation of water takes place through them, and if this is not checked and the loss sufficiently supplied from moist air or by other means, the chicks either die or are feeble.

It is, of course, impossible, in an article of this kind, to attempt to describe all the varieties of incubators which can be bought, or to recommend one over another. They all, however, have certain things in common, and, if each of these things be the best of its kind, the probability is that the incubator, as a whole, will be successful as a substitute for the hen.

A LAMP IN LIEU OF WARMTH OF WING.

The lamp is perhaps the most important part of an incubator, since upon its faithful performance depends the life-developing heat. Kerosene lamps are usually used, as they are preferable to gas, because they give an even, steady flame; whereas a gas flame will fluctuate in size during the day and night as the gas pressure fluctuates. The lamp should be large enough for thirty hours' burning, so that, if accident prevents its filling and trimming every twenty-four hours, there is a reserve supply of oil to run it until attention can be given it. The burner should be carefully selected for size, durability, and ease of working. Brass and copper are the best materials for a burner, never iron or tin, and any burner which has not a large, prominent lever or wheel for control of the wick, or which fails to work easily and exactly, should be refused. The chimney should be wide, easy to clean, and without projections to catch in clothing, which, indeed, applies to all the rest of the lamp.

The body of the incubator should be strong and plain, and not so ornamental as to catch dirt, or allow room for vermin. It should be mounted on strong legs, and high enough from the floor to be out of way of jars and careless feet. The incubator which has no part of its mechanism or regulator upon the top, is the better, other things being equal, since the top of the incubator, if it can be used as a table for turning or testing eggs, is a great convenience.

The egg tray should slide easily and smoothly—one which sticks or binds may easily ruin a whole batch of eggs. The tray should not go completely back to the end of the incubator or wholly fill the space, since to do so means the likelihood of decapitating some luckless chicken! Nor should the interior be crowded—too little space between the eggs and source of heat may mean difficulty of regulation and likelihood of ''cooking'' the eggs; and as for the nursery below, not to have it at least four inches high means cramped chicks. And chicks are feeble little things—their hold on their new life is tenuous, and their strength but little, and even so small an item as room to stand in may spell for them the difference between health and illness, perhaps even between life and death.

The thermometer inside should be easily read through the glass front—one which must be removed to be read is a source of danger, since it will change in temperature when it is taken from the machine, and the regulation of the temperature is very important. The regulating device should work easily and smoothly—those known as double-disk are decidedly the best, if the disks are large enough, say four or five inches in diameter, to provide for slight variations of temperature, and have force enough to move the damper.

Incubator experts insist that, after the selection of the proper kind of eggs, nothing is more important, in incubator work, than accuracy, exactness, and fidelity to a schedule. These things, and proper surroundings, will insure success. The proper surroundings are found in a clean, light, not damp cellar, or a room not dark, where there is not too much jar, too many air currents, or fluctuating temperatures.

Incubators should be worked for a day or so before putting in eggs, so that the temperature may be even throughout the machine, and the lamp and regulator adjusted so that the temperature stands at 100° F. The eggs, laid carefully on their sides in the tray, are then placed in the machine and maintained at this temperature until the end of the first day. By the end of the second day, the temperature will rise to 102°, because the eggs are now warm and beginning to give off a little heat of their own; for germination has started, and germination, or life, means heat. By the third day, the temperature should be 103°, and remain there. The lamp must be filled every day at the same hour, and the wick trimmed and carefully adjusted. After the third day, the eggs should be turned very carefully and gently, time enough being taken, but not too much time—five minutes should be ample—and this operation continued once a day until the nineteenth day, but not afterwards. It is then that the little chick, almost ready to come forth, has used up almost all his food, has found his position upright in the shell, and to turn him over is to place him so that he may drown or smother.

The eggs get their natural cooling in turning, and their ventilation at the same time, plus what is provided for them in the machine. Moisture has already been spoken of—it is better to have too little moisture than too much. A teaspoonful of water for twenty-four hours in wet weather, an ounce per twenty-four hours in dry, either rubbed gently on the eggs when turning or in a sponge in the tray, will be an average proper amount for one hundred eggs.

WONDERFUL GROWTH OF THE BABIES.

Eggs should be tested during the turning process, but not too often—on the seventh, tenth and fourteenth day is enough. The process of incubation is so wonderful, and the things to be seen in the egg so strange, that it is a great temptation to disturb the eggs oftener, but it should not be done, except as stated. Eggs are tested by placing them at the end of a tube of cardboard or tin, and looking through the tube at the eggs held against the light, preferably in a darkened room.

Eggs will show whether they are hatching or not within thirty hours from the first exposure to heat. Two little points can then be distinguished through the shell, indicating the head and the heart. Experts can see motion in the heart by the forty-fifth hour. By the fifth day, streaks, which are legs and wings, are seen. The liver shows by the sixth day, and the seventh develops the lungs, brain and stomach enough to be visible. Eyes appear by the tenth day, and feathers by the twelfth. In fifteen days the chick moves its bill, and in eighteen days the chick ''speaks'' or crys a little. Not all these things can be seen without experience, but it takes but little practice to tell the difference between fertile and infertile eggs, at the seventh day. The operator soon learns to distinguish between the spiderlike formation in the center with dark rays leading outward, which seem to move and float in the egg, denoting one which is hatching, and the egg which shows a dark, stationary spot with the reddish lines about it in a circle, denoting an egg which was fertile but now dead. And infertile eggs, of course, showing little or no change, should be removed from the incubator as soon as discovered.

The air cell, or empty space at one end of the egg, receives much attention from the incubator-manager, since, by its size, he tells if his eggs get enough moisture. Too large an air cell means too little moisture—too small an air cell, too much moisture. But judging its size is an art learned by experience only. By the sixteenth day, this cell or empty portion of the egg should be about a fifth of the bulk of shell, the chick occupying all the rest; shortly he breaks through into the air cell and breathes.

THE SUPREME MYSTERY OF LIFE.

And then, on the twenty-first day usually—it may be a day early or a day late—the chicks break through. Little fluffy balls of down they are, feeble and helpless, but alive, and as perfect as though they had a clucking mother to brood over and love them, for all they came from an affair of wood, metal and lamp! Yet, after all, a hen was their mother, though she did not tend them, for science, wonderful as it is, can not even tell what it is that makes life, or how the yolk and the albumen of our favorite breakfast food turns into a live bird. It is the Great Mystery, and to watch it, in an incubator, is an education in itself.

STILL THE LITTLE ORPHANS NEED CARE.

Feeding the young chicks, transferring to a brooder, or warm place, where the chicks can grow, and caring for them, is an art in itself, but, as in the incubator, care, attention, and following directions are all that is required.

Many young operators of incubators are disappointed that they get but few live chicks from a big batch of eggs. No matter how fine the machine, or how great the care, chickens won't hatch from infertile eggs, or eggs which have not come from healthy fowls. Hens which lay the eggs for you must have plenty of exercise, plenty of good food in variety, be kept clean, free from lice, and have plenty of good air and good water—particularly plenty of good water. To this end, some sort of a chicken-drinking reservoir should be used. They come in many forms, but the principle is the same in all—a means to keep water clean, to keep the chickens from roosting on the reservoir and soiling it, and to keep the water free from the dust and dirt of scratchings. A pan surmounted by a conical top with slits in the side, that the hens can poke their heads through to drink, set upon a pan on a shelf ten inches from the ground, so that the hens must jump to get their water, is one form. Another has a pan on a shelf, but covered with a board a few inches above the pan, so that heads and necks of thirsty hens can be poked in, while preventing them roosting above it, or on its edge. Do not have any drinking pan more than ten inches high from the ground, or the chickens will drink less water than they should.

COLD STORAGE EGGS BETTER THAN THEY SOUND.

The whole subject of chickens and eggs is intensely interesting, and in no department more than the cold storage of eggs, a development of the last twenty-five years. The idea which currently prevails, that an egg is fresh if it is recently laid, is erroneous. A forty-eight-hour-old egg, which has lain all night on a corn, hay, or wheat stack in a summer rain, may be quite unfit for food, swarming with bacteria carried through the porous shell by the water, while a six-months' cold storage egg may be quite fresh and good. Nor is a pickled egg—one preserved in "water glass" or silicate of soda—improper for food. There is no disguising the taste of a storage egg compared to a truly fresh, newly laid egg, but the idea that because an egg is several months old, therefore that egg is not good, is totally wrong.

Egg storage, when properly managed, with temperature of from 29° to 32° F. and with moisture properly regulated, is a legitimate industry which has made it possible for more people to get healthy eggs than ever before. In storing eggs properly and successfully, much more depends upon the time which has elapsed between laying the egg and preserving, than anything else. An egg fresh from the nest, put in storage immediately, will be infinitely better in six months or a year, than one a week old, similarly treated. And eggs, cooled soon after laying, will ''store'' much better and longer than those which are allowed to remain warm. For, while cold storage arrests the chemical changes which take place within an egg, it only checks them, and the perfectly good egg, taken from storage, may spoil in a day or so if it was not strictly fresh, newly laid, and properly cared for, when it was first put in the warehouse.

It will astonish many to learn that it is impossible to tell a cold storage egg from a perfectly fresh one, except by breaking and smelling, or cooking and eating; for if the ''newly laid egg'' is a few days old, and the cold storage egg was stored as soon as laid, even an expert may be deceived and say the storage egg is the fresher. But, in large lots, an expert egg tester can easily tell a storage egg from those unstored, because all storage eggs will exhibit a uniform shrinkage in contents, and the ''candler,'' as the man who tests eggs by a light is called, can see this. He can also distinguish a case of storage eggs from a case of fresh ones by the mould on a cracked egg in the storage case, and by certain kinds of ''spot rots'' peculiar to storage eggs, particularly if the air in the storage plant has been too moist.

CHAPTER XVIII.

The Canning Industry.

EATING IS AN OLD HABIT—BUT NOT CANNING.

SOME ways of preparing food are so old as history, but now and then we find a process which is quite new. Canning factories were never even heard of until late in the nineteenth century. Before canning was devised, the only way to make things "keep" was to dry them, and perhaps to add a good deal of salt or sugar. Canned food has generally been cooked, but not always. The can must be air-tight and filled with food, so that there is no air in it when it is sealed up. If this is perfectly done the food will keep.

THE GREEDY APPETITES OF BAD GERMS.

The reason why air must be kept out is that it contains myriads of tiny plants and animals, with names a thousand times longer than they are, and they need only the food they find in liquid or solid substances to set up a flourishing plantation. And when they do that, it spoils the food for our use. The mould-plants make up one tribe of these little enemies of human food; the yeast-plants and their cousins another; and there are animal beings too small to be seen, waiting to plunge their greedy little appetites into wholesome food before we get a chance at it. There are "good germs" and "bad germs;" it is the bad germs we want to shut out, for they are all food-spoilers in their various ways. Among the worst of them, are those that get into ice-cream, and all sorts of other good things, and give people what is known as "ptomaine poisoning."

Salting, smoking, and drying, by sealing up the juices of meat, fruit, or vegetables, keep out most of these pestiferous little creatures—all of those which cannot live without moisture. But these methods change the taste of the food. The canning-factory gives us freshly cooked food just as it went into the cans—if the work is properly done. This has never before, in the history of the world, been a possible achievement.

We all know that, when people are doubtful about the wholesomeness of drinking-water, they boil it, and this kills the germs, for no living thing can stand being boiled. For the same reason, most of our canned food is boiled or steamed, and put into the cans while still boiling; the cans are filled brimful, and the covers put on at once. This makes it impossible for any germ, animal or plant, to get into the can until it is opened; and though it may stay unopened for years, and be carried to the tropics or the Arctic Circle, yet, when it is opened, the food will be sound and sweet. The only misfortune that can possibly happen is some imperfection in the tin, if the can is made of tin, which may let acid juice, like that of tomatoes, get at the metal of the can; in that case there will be a chemical change which affects the taste. Many people will not eat tomatoes put up in tin cans on this account, but buy all their fruits in glass cans. Of course, no fruit acid can possibly suffer any change in a glass can.

WORK THAT TRIES THE TEMPER.

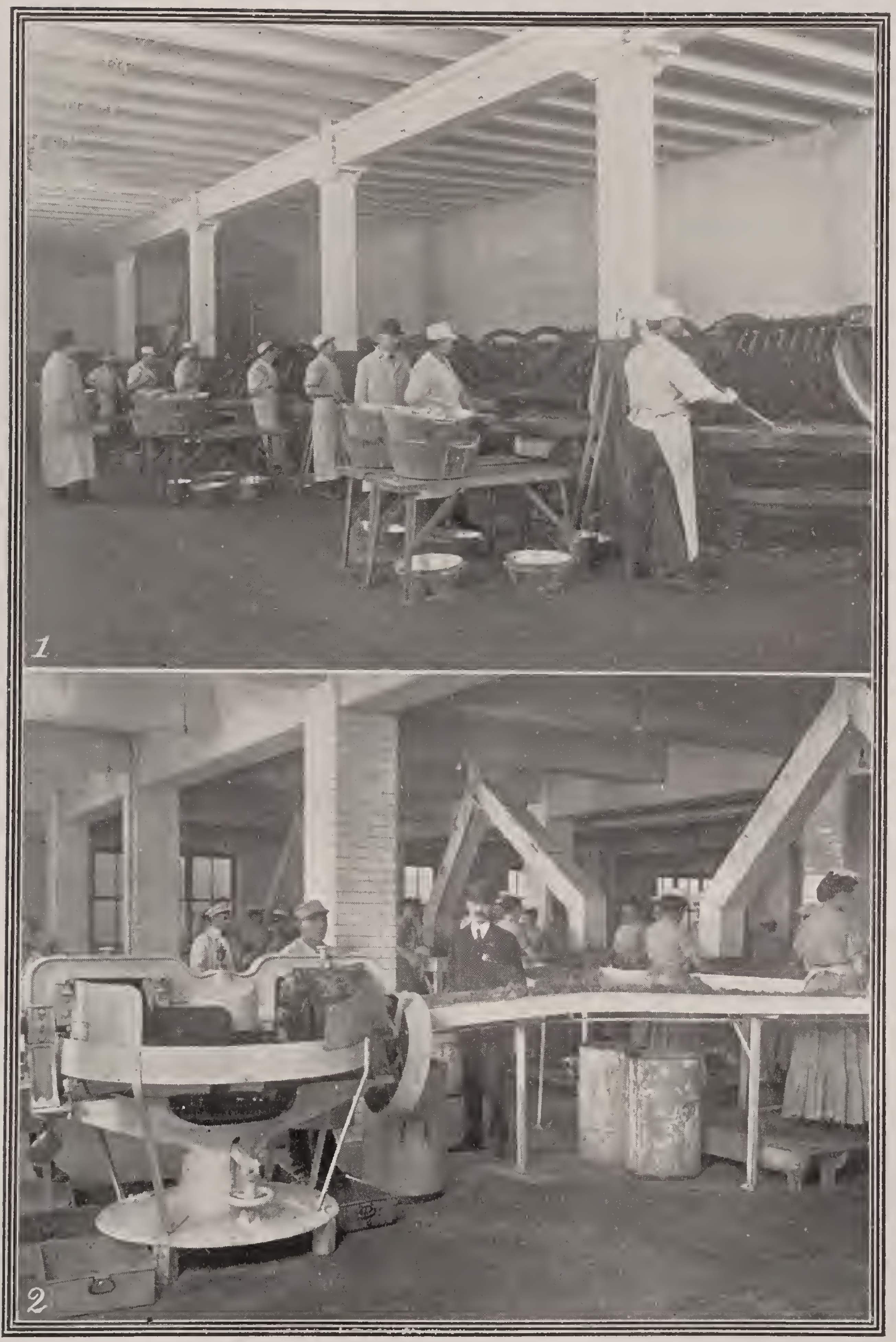
When it was found that glass cans could be sealed so as to be perfectly air-tight, by using a porcelain-lined metal cover and a rubber ring between the cover and the can, most women began to can fruits and vegetables at home every year. They did not often preserve meat, however, because meats have to be heated a good deal more than fruits do, and fruits are canned with a great deal of sugar and spice that help to keep them. They will last perfectly, too, if they are put up in brandy; but this is even more expensive than the sugar used in preserving. It took some time to so perfect the glass can that would not break when the hot fruit was poured in. In the home-preserving-kitchen, the housekeeper had to set the cans in hot water, with hot, wet cloths wrapped around them, taking great care that a draught of cold air did not strike the cans while hot, and filling them as quickly as possible so that they could be sealed hot. Altogether, it was a very troublesome and temper-trying business. What made it all the worse was, that all this had to be done in the pleasantest of summer weather, and everybody in the house was obliged to lend a hand in paring and stoning fruit, or scraping corn off the cob, so that what was ready for canning might be canned before it spoiled. If this work was not done, the family could not count on any fruits or fresh vegetables for the other two-thirds of the year.

THE HOME KITCHEN AND THE CANNING FACTORY.

The first canning factories followed the plan of the home kitchen, and the work was mostly done by hand, often not by very clean hands, or in very clean rooms; nor were the factory-managers always careful to use good fruit. For this reason, long after canning factories had begun their work, people who were careful about their eating preferred to take the extra trouble of making their own preserves. Today the best canning-factories are kept as clean as a Quaker kitchen; only the very best materials are used, for many of these factories have their own farms and orchards; and nearly everything is done by machines invented for the purpose, so that the food is hardly touched by the hand at all.

A VISIT TO A CANNING FACTORY.

The two great changes in the canning factory in the last twenty years have been canning machinery



1. Chopping Sausage Meat. 2. Making Chopped Meat.

and can-making machinery. The tin can today is made so cheaply and so well that it does the work the glass can used to do.

Let us, in imagination, go through a first-class factory, where meat, soups, and puddings are made. What we see going on here is done in very much the same way in a first-class fruit-preserving factory.

The factory is in a building standing by itself, so that it gets plenty of light and air on all four sides. The first room to be visited is where the meats and vegetables are kept, for a few hours, while waiting to be cooked. It is as cold as an ice-chest and very clean. From this room the food is brought to a large, light room with many tables, where men and women, in clean, washable uniforms, sort and scrape vegetables which, after this, are not again touched with the fingers. There are paring machines that pare some of the vegetables, and cutting-machines that cut them into dice shaped segments. The cutter drops the bits of carrot, potato, or turnip into a sort of revolving colander that lets every piece, which is not a perfect cube, fall through. The imperfect pieces are used in thick soups, but the pieces for clear soups are all perfectly dice-shaped. Other machines cut up thin slices for Julienne soup, or mince vegetables, fruit, and suet for puddings.

The cooking is done in enormous kettles, each with an overhead ventilator to carry off the odors. In this great room, where enough soup is made every day to feed a small city, there is not as much smell of cooking as there is in an ordinary dining-room at dinner time. All the people in the factory wear uniforms, and not a bit of outside dirt ever gets in, except what may come on the shoes—and even that is scrubbed off the floor in a few hours. The coal-cellar is not scrubbed, but the floor is swept clean; everywhere else, daily scrubbing is the rule.

A FACTORY THAT MAKES CANS AS WELL AS FILLS THEM.

In this factory, as in all the big ones, the cans are made on the spot. Down in a separate room a special force of men is at work on sheets of tin. One machine slices off strips for the sides; another cuts round pieces for top and bottom, as a biscuit-cutter punches from dough; a third machine bends the can into shape; and still another solders on the bottom. It is the sole business of two men in this room to examine every sheet of tin, to make sure it is perfect.

The finished can is placed in an enormous wheeled basket and whisked to the kettle before a speck of dust has time to strike its shining sides. Having been filled with one deft motion of the dipper, it is sealed up, slid off to be labelled, and finally is stacked away in one of the wooden boxes in the basement. There is one huge room full of boxes containing cans of soup and meat, stacked up to the ceiling—and the ceiling is high.

CANNING ON A LARGE SCALE.

When food is canned in this business-like way it is really cleaner than it can be when it comes from the market, and there is never any trouble about its keeping fresh. In such factories people are not only allowed, but invited, to go all through the building and look into every corner. If any one had done that in an old-fashioned canning factory he would never have touched canned goods again.

Another reason why canned food is cheaper and better than it used to be is that every bit of material is used for something. Chicago packing-houses boast that they ''use all of the hog but the squeal,'' and nothing that an up-to-date factory buys is wasted. The white meat of a chicken is canned for boned chicken; the bones and the rest of the meat are made into soup, or essence of chicken. The skin, horns, tallow, and every other part of every animal can be used somehow, in making buttons, leather, soap, brushes or some other sort of goods.

Still another great improvement is in locating the factory near the farm. Instead of bringing California fruit in carloads to some Eastern city, we begin to find California fruit-growers building their own factories, canning the fruit on the spot, and saving railroad bills and waste through spoiling on the road. One of the latest jumps of the factory is across the eastern half of the Pacific ocean to Hawaii. The pineapple ranchers of the Sandwich Islands are beginning to make sliced pineapple, grated pineapple and pineapple juice on their own land.

ALL THE WORLD A-CANNING.

We get canned goods from Europe, especially certain fine preserves that are made over there with a nicety we have not quite learned. The famous Bar-le-Duc jams, for example, are all sun-cured fruits, with the flavor of the country they grew in; and we may imitate, but cannot equal, Oriental sweetmeats, because we have not the fruits of which they are made. Some of the English, Irish and Scotch jams, too, have a flavor of their own, and there are Italian salad-vegetables put up in olive oil which we do not make here.

Sardines are canned on the coast of Maine and many other places, but the real sardine comes from France. It is a little fish of a special flavor, and the imitation sardines are likely to be herring, or some other fish, taken young—which is not the same thing at all. On the Breton coast sardine fishing is a source of considerable income, both to the fishermen who catch the fish and the women and girls who pack them. At the usines, as they are called, one may see girls in the quaint, full skirts, white caps, wooden shoes, and kerchiefed bodices of the Breton peasant, deftly packing the little fish from early morning until late at night, in the season, and, for these long hours of work, earning wages which would seem to us hardly worth working for at all, but which mean much to them. Indeed, the reason why some of the European canned goods are better than ours at the same price is due to the low wages that are paid there. When labor can be had for next to nothing, it makes quite a difference in the price of, say, a jar of jam; and this is especially true where the whole population of a town or countryside works at one trade—in Dundee, Scotland, for instance, where they really do not do much else than make jam.

From Europe we get many kinds of canned fish besides sardines—Yarmouth bloaters, kippered herring (both of which are herring cured and smoked in different ways), mackerel put up with French sauces, anchovies, ''Bombay ducks'' or bummaloe fish, Findon haddock, and tunny fish.

We are even beginning to get canned goods from Japan. The Japanese crab is put into a can before he is more than fairly out of the water, and comes to our tables by way of San Francisco.

PUNGENT PICKLES AND PRESERVES.

Mulligatawny paste is an English preserve; but mulligatawny sauce is a fish-sauce made in India, and, like chutney, mangoes, preserved ginger, chowchow, and chili sauce, became popular in England because people who had lived in India learned to like native preserves and pickles, and wanted them at home. As the natives of India used to have no canning factories and, indeed, have very few, even yet, the only way they could preserve fruits at all was by using strong spices, sugar, and vinegar in one way or another. Moreover, in very hot countries such strongly spiced and peppered foods are good for the health, especially when they are eaten, as they generally are, with rice. That is why Indian preserves are almost always rich and hot with spices, sugar, and pepper, and why the preserving factories of Bombay, that prepare this hot stuff for the foreign trade, supply a demand that is growing all over the world.

A PRETTY STORY WITH A PEPPERY TANG.

We shall find among the sauces that come from any hot climate the same peppery flavor, and the hottest of them all, tabasco, which is made in Louisiana, has a rather romantic story. Tabasco sauce is made from the berries of a special kind of small pepper-bush, which, before the war, grew on an island that was part of the estate of an old planter who took a great interest in good cooking. He experimented until he made from these berries a pepper-sauce which was his own secret, and every year, on a special day he invited a few old friends, who knew a good dinner when they ate it, to a feast whose ingredients went with this sauce. Then the war came, the old planter died, his fortune disappeared, and when his daughter came back to the old home the plantation seemed to be a wreck. But she found, one day, a single shrub of the little pepper-bush left, and it occurred to her hospitable soul that it would be a good idea to make some of the old, hot sauce, and, on the day when her father had given his annual dinner, to send a little bottle of it to each of his old cronies. One of these friends of her father happened to live in New York. He served the sauce at a dinner, and mentioned the fact that the lady who sent it to him needed money. One of the guests was a manufacturer, who said that she had a fortune in that sauce. And the outcome of the whole story is that down in the southland, there is a large pepper plantation, with a factory nearby where the famous tabasco sauce is made in enormous quantities; and that a little woman, who put into action a kindly thought, was thereby placed far beyond the reach of want.

THE OLD FAMILY RECIPE BOOK.

This is the way in which a great many of the best sorts of canned goods have been made. Somebody's grandmother, or aunt, or cousin had an old, never failing, family recipe for canning or preserving fruits or vegetables, and this recipe was finally used for millions of cans, instead of making just enough for the family table. Not a few large preserving and canning factories have grown up out of a home kitchen. Somebody made preserves that were good enough to sell, and kept on making more and more of them, and perhaps invented new ones, or patented a new sort of can, and so the business has grown. Here and there, too, we find a recipe which was invented by some famous hotel cook.

THE JOLLY GOOD JAMS OF ENGLAND.

English people eat more jam than any other people in the world. They serve it at breakfast and at afternoon tea. And they make enough of it in England and Scotland, not only to supply their own tables, and those of the English all over the world, but to send a good deal to our market.

To make English jam, the fruits are stemmed by machines, and are then cooked until they are soft enough to be put through other machines, like sieves, or colanders, to get rid of the seeds and skins. Then they are cooked a little more to thicken them, and kept in stoneware jars until the fruit season is past, when they are cooked again and put up in the little stoneware, glass, or earthern jars in which they are sold. Generally, the jam is first covered with a piece of oiled paper and then corked and sealed, but some manufacturers place only a piece of paper over the top and tie it down. Most of the Irish jams are put up in this way, and are combinations of two fruits—apple and gooseberry, for example. In England, it is quite safe to send a box of jam packed like this, because the porters are careful in handling it "right side up with care." But the first merchant who ordered a case of Irish jams sent to America forgot to order the jars well corked and packed. The boxes came all right enough; but the jars, with only thin pieces of paper over the tops, were swamped in a sea of gelatinous jam.

Orange marmalade is a favorable jam in England, and is made of oranges and lemons cooked together, along with the thin skin, and this addition of the skin turns the fruit into a jelly-like sweet. Ten per cent of starch sirup from America, made of corn, is added, and this is why the English jams are better than those from Germany, because German cooks generally use potato starch, which doesn't give so fine a flavor.

JELLY-MAKING IN FACTORIES, AND "MAKING JELL" AT HOME.

Jelly-making in factories is a somewhat different process from the old familiar home ways of "making jell." To have the jelly clear and firm, fruit must be used before it is too ripe, boiled slowly until it is just thick enough, and then put into a flannel bag with a pointed bottom, and left to drip. The clear juice, when cold, makes jelly that will turn out of the glass in a firm mould. But a great many people find this too slow and hard a job, and they mix the fruit juice with gelatine or some other prepared jelly to help it stiffen. A little apple-juice will often "jelly" other fruits, and there are some chemicals which are used in cheap jellies, though the color is more than likely to be aniline dye, instead of currant juice. There is no method of manufacturing jellies in quantities that gives them just the tart, delicious flavor of the old-fashioned jelly made of fine, firm fruit, a little at a time, in the patient, old-fashioned way. But as long as chemicals are not used, a little apple juice or gelatine will not prove unwholesome. The surface of the jelly is usually covered with a little melted paraffin. This keeps out the air, and can be taken off, melted, and used again, over and over, because none of the jelly sticks to it.

The time may never come when, for reasons stated, no more preserving will be done at home, for the knack of jelly-making runs in families and, handed down from mother to daughter, can never become a lost art. But factory-made jellies are all that most people can hope to attain, and their real savoriness and many excellencies, together with their cheapness, attest a wide popularity that will grow with the years.

CHAPTER XIX.

The Fruit Industry.

THE LUSCIOUS FRUITS OF TODAY.

MODERN fruits are so delicious—luscious, indeed, is the word to apply to most of them—so abundant and easily obtainable the year round, so wholesome and necessary a part of our diet, and such universal favorites as food, that it is hard to realize a time when people had to get along without them or could obtain only a few hard, juiceless, inferior kinds. They are one of the many good things that make life now worth living, as compared with the meagre fare of the childhood of the race.

A DISCOMFORT AGE OF THE RACE.

Fruits have grown wild all over the world, especially in tropical and semi-tropical countries, from the very beginning of the time when green sprouts peeped forth from the bare soil. Then, as animals and men came on the scene, they found that the little hard, round things growing on bushes and trees and vines were fairly good to eat, and made a pleasant change from the meat diet they had obtained by feeding upon one another. So fruit-eating must have formed one of the first steps away from cannibalism and barbarism, coming even before the use of grain; for grain had to be prepared, as a rule, before it could be eaten; while all one had to do with fruit was to go out and pick it. But what a wide-spread, universal discomfort must have ensued from eating the tough, gnarled, bitter, dry, uncultivated lumps broken off or knocked off from trees; worse yet, and more painful to contemplate, hunger must have often got the better of their patience and led men to eat fruit green!

MODERN FRUIT MARVELS.

A far pleasanter view of the subject is the new view. The evolution of the fruit industry to its present proportions is one of the marvels of latter-day methods. It is made possible, first, by a radical change in fruit-raising itself, including propagation, grafting, budding, spraying, irrigation, and many scientific devices for increasing size, variety, and flavor. Picking and packing are now so carefully done, refrigeration is so exactly applied, and, most important of all, transportation is so speedy and universal, that fruits of all climes may be obtained at reasonable cost, at one's very doorway, in any civilized country, the year round, and in endless succession and profusion.

THE ORCHARD AT THE DOOR.

One can hardly realize what this means in health, comfort, and enjoyment, unless he goes back a few years—and he needn't go back far. Ask father or mother about the time when, as a rule, the only fruit came from the trees or vines planted "around the house;" when one of the delights of a visit to "the old folks" was to get "a taste of fruit," usually apples—good ones, too, Rhode Island Greenings, Pound

Sweets, or Pippins—and when a barrel of apples found their way, once a year, from the old farm to the city cellar. Berries could be purchased, to be sure, and cherries, pears, plums, grapes, and such home-grown fruits—perhaps they were a little cheaper, too, than they are now; but "the season" was short, and they had to be caught on the wing or not at all. Peaches were somewhat rarer and costlier; the exotic orange was hardly to be thought of except as a luxury; bananas were unknown in the North, and have had to fight their way to popularity; indeed, there were only a few notes in the fruit-scale, to be struck here and there, where now is a symphony in continuous performance. In the United States alone there are over one hundred and fifty species of fruits that are fairly well known, and at least fifty important commercial kinds.

CLASSIFICATION OF FRUITS.

There are three general heads under which most fruits may be grouped:

- Orchard or Tree Fruits.
  - Pome fruits—Apples, pears, etc.
  - Drupe fruits—Peaches, plums, cherries, etc.
  - Citrus fruits—Oranges, lemons, etc.
  - Nuts—A fruit with a hard shell.
- Vine fruits, principally the grape.
- Small fruits, berries of all kinds.

THE WHOLESOME, HOME-LOVING APPLE.

Where there are so many fruits, and each fruit a favorite, it is difficult to make selection of even a few for special mention. If one does attempt to do this, perhaps he will not go far astray in giving the apple the first place. It is, more than any other, the home fruit; like the robin, the nearer to the house it can get the better satisfied it seems to be. It is certainly the best known fruit and, probably, the most wholesome; the most extensively raised, too, for the apple will grow almost anywhere, especially in North America, which is the leading apple-growing country of the world. Her full crop approaches three hundred million barrels annually. The old apple orchards of New England and the East are falling into decay; but the land is there, as well fitted for its old-time apple harvests as ever, and a movement is now under way for bringing back, under intensive methods, the former cultivation of the apple. Meanwhile, the Middle West and the Coast are supplying America and part of the Old World, with enormous, richly flavored, fine-fleshed, ruddy or golden apples that contribute to the health as well as pleasure of mankind. For, be it known, an apple or two a day is so antiseptic and has so many life-giving qualities that it will go far toward imparting to the system a tone that will scare off disease and scale down the doctor's visits to a minimum.

The apple is native to southwestern Asia and adjacent Europe. It has been cultivated from time immemorial, charred remains of the fruit being found in the prehistoric lake dwellings of Switzerland, not to speak of the mention of the apple in the opening chapters of Genesis.

THE JUICY PEAR, COUSIN TO THE APPLE.

The pear is a cousin of the apple, but, for many reasons, not so popular. It is more difficult to raise, does not keep into the winter, is not so prolific, and, while most varieties are very juicy, sweet, and pleasant to eat, they do not possess the dietetic qualities of the apple. Indeed, most people cannot eat pears freely. This fruit came to North America from Europe and also from the Orient, and is cultivated in Canada, the eastern part of the United States, and on the Pacific slope. Over six million bushels are raised in the United States annually.

THE SOFT-CHEEKED PEACH.

The peach, noted for its flavor, as the pear for its juiciness, is also a native of the Orient, having come to us from China. It has been cultivated since prehistoric times; originally, it is supposed, the peach and almond were identical. If so, what a reversal of parts has taken place!

Peaches are raised in many different "belts" of the United States and even lower Canada, along the lakes. Delaware peaches were known and prized before the Revolution; and the story of the Lake Michigan peach belt, which dates from Civil War times, reads like a romance. Over three hundred varieties of this delicious fruit are raised in the United States; they are popularly classed as freestone and clingstone, white-fleshed and yellow-fleshed.

PLUMS AND PRUNES.

Plums, as found in North America, are of a mixed type. There are the domestic plums, including the damson, green gages and prunes—the latter now enjoying a revival of culture and rapidly increasing in commercial value. Then there are the apricots, a Chinese plum, introduced into this country about thirty years ago, and grown extensively in California; and the Japanese plums, which seem to be generally adapted to culture this side of the Pacific. The production of plums and prunes in the United States now exceed nine million bushels annually.

A GOLDEN TALE OF MAGIC.

The citrus fruits, of which oranges and lemons are the best known, have put a golden girdle around the earth from Indo-China, where they started. On the shores of the Mediterranean, and in favored spots of the United States they have displayed their radiant beauty, pleasing to the eye and palate alike. Almost all the year round there is something doing in an orange or lemon grove, especially in California; and the introduction of irrigation—furrow irrigation—is extending citrus culture and increasing the yield, if that is possible, in groves that are already bending with abundance.

In the time of our grandparents the best oranges were grown under glass in southern Europe; and to find an orange in the toe of one's stocking at Christmas, was a rare and lucky piece of good fortune. Oranges were cultivated in Florida from the first entrance of the Spaniard, and orange groves almost carpeted the State until the great freeze of 1894-1895 destroyed 90 per cent of the trees, and cost the Florida orange industry $100,000,000. Since that time, a part of the acreage has been restored, though not to its former extent; and by the introduction of various means of protection against frosts, notably screens, tents, and sheds, the danger of another wholesale destruction of groves by freezing is, it is hoped, a thing of the past.

The orange industry in California was being pursued with somewhat indifferent success until an event occurred whose golden fruitage rivals in importance the discovery of the golden metal, years before. The thrilling incident will be rehearsed in song and story wherever the luscious ''navel'' orange brings its refreshing cheer. It was in 1870 that William F. Judson, American consul at Bahia, Brazil, found a seedless orange growing on the banks of the Amazon. Amazed at such a phenomenon, he secured several shoots of the tree and patriotically sent them ''on to Washington,'' thereby performing a service for his country that transcended in importance many a warrior's deed. Luther C. Tibbitts and wife, of California, were in Washington at the time, and, when they returned, Mrs. Tibbitts carried with her four of the little shoots, and very carefully planted them in her garden. One gave up the struggle to fulfil a glorious destiny, and died, perhaps of homesickness; another was devoured by a greedy cow who knew a good thing when she saw it. But the other two lived and throve and, five years later, produced sixteen great oranges that—wonder of wonders!—were seedless, and richer in flavor and larger in size than had hitherto been tasted and seen. Then began a new era of propagation, which started slowly and expensively, for buds from the original trees were comparatively few, and commanded high prices; but, once geometrical progression was applied, California came into its own. Fifty million dollars are now invested in the culture of the navel orange, and another fifty million in related industries. The orange output in a recent year was over thirty thousand carloads, which would make a train of cars stretching from New York to Boston. And what became of the two little shoots that started this untold blessing? Only one survives and this was transplanted, in 1903, from Mrs. Tibbitts' garden to the courtyard of the Glenwood Hotel at Riverside, Cal., being assisted in the ceremony of honor by no less a personage than Theodore Roosevelt, President of the United States.

Lemons require much greater care than oranges, but, owing to the increasing demand, are a profitable crop. Their dietetic value is very great, and many uses are made of the citric acid obtained from the juice and of the oil extracted from the peel.

A RICH FRUIT FROM POOR LAND.

The grape is one of the oldest of domesticated fruits, for we meet it in history as far back as the time of Noah, whom it involved in some trouble. In Europe it is raised chiefly for wine; but, on this side of the Atlantic, where wine drinking is not so general a custom, the grapes are made into raisins or used on the table; unfermented grape juice is also becoming popular as a refreshing drink.

The introduction of the grape into America was accomplished through many difficulties, the Old-World type, the vinifera, being adapted especially to the Pacific coast only, and other kinds, of the table variety, being often unaccountably freaky until the right localities were found. It was only when the fact was discovered that ''poor land''—that is, land poor in nitrogen—was best adapted to grape culture that the vine came into full fruition. Now there is no other country of the world so rich in species as North America; and vineyards are well distributed over the country, though there are certain spots that grapes seem to ''take to''—notably western New York and Northern Ohio. The names of many of the varieties are household terms—the ''Concord,'' ''Catawba,'' ''Isabella,'' and, within the last few years, the ''Niagaga.''

The grape is one of the most wholesome of fruits, and possesses qualities that give the ''grape-cure'' a place of some value in dietetics.

Thirty years ago raisins were produced only along the Mediterranean. Now American production is over one hundred million pounds annually.

THE LARGE SUBJECT OF SMALL FRUITS.

Small fruits—the berries—can only be alluded to. It would be pleasant to linger with the strawberry. ''Doubtless,'' said an old English writer, ''God might have made a better berry than the strawberry, but doubtless God never did.'' It is one of the few fruits that have not been improved in flavor, though it has in size—the tiny, wild ''field strawberry,'' with its little tapering tip, having a rare, sweet, woodsy, aromatic flavor which, like the fragrance of the trailing arbutus, lies so close to Nature's heart that the secret can never be stolen and artificially developed. The eastern strawberry season now begins in early spring and continues to late July, if one starts in Florida and works his way north, as the berries do by modern transportation; and it is one of the joys of California life that the strawberry lasts practically all the year through.

Raspberries, red and black; currants, red and white; blackberries and blueberries—of all these, every kind had been improved and specialized into different varieties, except the blueberry which, it was thought, could not be domesticated. But recently experiments have been conducted looking to the cultivation of the blueberry, with surprising and gratifying results—so what may not the "huckleberry pie," juicily good as it is today, come to be in the future. The cranberry, too, is receiving cultural attention and anti-frost protection, so that this Thanksgiving dish, which stands side by side with the turkey, may not be displaced.

FIGS, DATES, AND BANANAS ARE GETTING NATURALIZATION PAPERS.

Reference must be made to figs and dates, which foreign trade has formerly monopolized, but which are fast becoming Americanized. The date palm in Europe always clung to its desert environment; but on this side of the water it has been coaxed to grow in less austere surroundings and is really becoming quite companionable. The Smyrna fig is now raised with great success in the southwestern part of the United States, and in California, since the government has succeeded in getting that particular little stinging wasp to feel at home which is best adapted to pollinate the fig. The American fig, which grows by budding from the stem, and does not require waspish assistance, grows abundantly in Georgia and neighboring states.

Efforts have recently been made by the United States government to secure greater cleanliness and care in the preparation of figs and dates abroad, "so that the worms and dirt may be reduced to at least less than one-third the total bulk."

The increase in the importation of bananas has been one of the wonders of the fruit industry. In 1870, only a few hundred bunches were brought into the United States, and they found slow sale; now about $10,000,000 worth are imported, mainly from the West Indies and Central America, and they are reckoned as the most popular as well as nutritious of imported fruits.

THE "RICH, BROWN NUT."

Nuts are a fruit with a hard shell. Most of them grow "wild," though the chestnut, to a small extent, and the pecan, much more frequently, have reached the cultivable stage. Peanuts and almonds are excepted from this statement, as they are not, botanically speaking, true nuts. Chestnut trees in New York and New England are perishing from a new form of blight, the ravages of which horticulturists are endeavoring to combat, and to supply the loss by cultivation. The pecan is a species of hickory and is passing quite generally, in the south, into the cultural era. The reasons for its increasing popularity are to be found in its rapid growth, great productiveness, the thin shell with good crackable qualities, and the full kernel of dainty flavor. The food value of nuts is just being discovered, and their rich nutritive qualities are giving them their rightful place on the table along with the juicier kinds of fruit.

The butternut, hickory nut, walnut, chestnut, and hazel nut are all the lawful prey of predatory or foraging excursions known in the golden lexicon of youth as "nutting parties." And if one has not enjoyed the delight of these quests for brown fruitage—why are nuts almost invariably brown?—he should accept the first invitation he gets to "go nutting."

THE ERA OF NEW AND IMPROVED FRUIT.

The United States government is scouring the world for fruits that may be introduced and acclimated, as well as devoting much time and attention to developing new varieties of native fruits, and a bulletin is issued annually, describing such varieties as promise the greatest success. Many experts are working upon similar lines, notably Burbank, to whom the Carnegie Institution recently made a grant of $100,000 to enable him to give his entire time, unhampered, to his wonderful work of grafting, cross-fertilization, and experimentation with fruits and vegetables—a work that has already produced such wizard-like results. What new and delicious fruits the future has in store for us, from all this research and activity, we can only conjecture!

''PLEASANT TO THE SIGHT AND GOOD FOR FOOD.''

The dietetic value of fruit cannot be too strongly insisted upon. It is not over much to say that we could not have brought our bodies and brains—the most complex and delicately organized machine in the world—to their present perfection without the aid of fruits. Fruit should be eaten freely, to the extent of at least 15 per cent of our daily diet—in summer much more. Some kinds are more wholesome cooked, others raw; or they possess distinct and different value in both forms. Uncooked fruits should never be eaten when green or over-ripe; the ''golden mean'' is a golden rule here, as everywhere. Each individual should find out for himself which fruit-acids and fruit-sugars agree with him best. A little experimenting will point the way, and even the investigation is a pleasant path. The result will invariably be that nearly every fruit will be found, like most of that in the Garden of Eden, ''pleasant to the sight and good for food''—good to the taste, and good, oh! so good, for health.

CHAPTER XX.

Sugar and Candy Making.

OUR GRANDMOTHER'S OLD CHINA SUGAR BOWL.

ONE of the changes in our language is the change in the meaning of the word sugar. Today, when sugar is mentioned, we take it for granted that fine white sugar—the granulated sugar that everybody buys—is meant. But your grandmother lived in the palmy days of delicious, homemade maple sugar; of honey—and ‘‘sweet as honey’’ was a proverb; of the sticky but succulent molasses that fitted so well ‘‘on top of bread’’; and of loaf sugar in the form of pretty white cones, wrapped in tempting blue paper. This kind of sugar was too costly for mere children, and its only mission was to be ignominiously broken into bits for coffee or tea, or pitilessly pounded into powder, when fine sugar was required.

And our grandmother's rich brown sugar, in whose lush depths lay lumps of mouthful size! The boys and girls of today have surely missed half their heritage who do not know how good those lumps of brown sugar tasted that their fathers and mothers, when *they* were children, used to get for ‘‘being good,’’ or would themselves surreptitiously extract from the old china sugar bowl, when the craving of the ‘‘sweet tooth’’ got the upperhand.

FROM SAP TO SUGARING-OFF.

Maple-sugar we have today, and it tastes as good to us as it did to our fathers and mothers—when we can get it pure. That is the real difficulty, for, at least before the Pure Food Law was enacted, it was said that more ‘‘Vermont maple sugar’’ was consumed in Chicago alone, in a single year, than Vermont produced in two. And one who hasn't eaten the splendid light yellow, fine grained "Vermont sugar," that has such a woodsy flavor and just melts in the mouth, has missed one of the joys of life. Its manufacturing is so interesting and so tinged with touches of romance that an account of it will not be out of place here.

Maple sugar was first made by the Indians, and is one of the important crops in the mountain country of New England, New York, the Middle West, and Canada; but the greater part of it comes from New England, especially Vermont. Sugar can be made from the sap of several trees, but the best for the purpose is the sugar-maple, which generally grows on rocky hillsides. In the latter part of March or early in April, when spring-like weather comes on, and the sun calls the sap from the roots into the branches, the farmer who has a "sugar-bush" or "maple-orchard" (it is called by both names) begins to get his buckets and kettles ready. He usually has to go into the woods on snow-shoes, because the snow lies there late; and he starts early in the morning, while there is still crust on the snow. A little hole is bored in the trunk of the tree just deep enough to let the sap trickle out, and in this hole a wooden spout is placed, from which a wooden bucket is hung. Every morning the sap is emptied from these buckets and taken to a little sugar-shed built close by, for the sugar-trees are often so far from the farmhouse that, during the sap-running season, the sugar-makers live in this hut and sometimes sleep there. When there is sap enough to fill one of the big kettles, the sugar-making begins. The sap, as it comes from the tree, tastes like sweetened water and looks like it, but, as it boils, it gets thicker and thicker, and the fires must be carefully tended, so as to prevent its scorching. The first sap makes the best sugar, for, when carefully boiled down, it will be almost white; it could be refined into pure white sugar, but nobody takes the trouble to do that. Children, during the sugar season, have great fun with maple wax, or "jackwax," as it is often called, which can be made from maple syrup at any time. When the syrup is thick enough to "gum" on being dropped into cold water, it is spread on snow, or a chunk of ice, and turns to a sweet wax which is delicious. But this is not part of the sugar-making business, though "sugaring-off" is a great part of the fun of an old-fashioned sugar-party.

Sometimes the maple syrup is put up in sealed tin cans; sometimes it is boiled down so that it is like moist brown sugar, and packed in tin cans; and sometimes it is boiled still more, and put into tin moulds, where it hardens into cakes that you cannot bite, but have to break up with a hammer.

OTHER SUGAR IN THE NORTH.

But the maple tree is not the only course of sugar supply that is found in northern latitudes. There is more or less sugar in most vegetables and all fruits, but usually the vegetable or fruit is worth more for some other use than the extraction of sugar. Beets, however, are an exception, as they contain a larger percentage of sugar than any other vegetable, and can be raised to excellent advantage, as sugar producers, in California, Oregon, Utah, Colorado, Wisconsin, Michigan, and several other States. In 1909, the total output of beet sugar in the United States amounted to over four hundred thousand tons.

HALF-WAY BETWEEN NORTH AND SOUTH.

Going further south, we come to the sorghum belt which lies particularly in Kentucky and Tennessee and a strip of land, extending westward, in about the latitude of those States. Sorghum is a kind of tall cane which looks like Indian corn and is sometimes called Chinese sugar-cane. In the Orient the seeds are used for grain, and sometimes the plant is raised for that purpose in this country; but it is mostly grown for making sorghum molasses, a lighter and sweeter molasses than that from sugar-cane.

SOUTH NOW—BUT, FIRST, MOLASSES.

Speaking of molasses, it is worth noting that the real article comes from New Orleans or Porto Rico, though these so-called brands may really be made almost anywhere else—in Rio Janeiro or some other part of South America, or Cuba. The annual production in the United States is about twenty-five millions of gallons.

THE WHOLE SEMI-TROPICAL WORLD A VAST SUGAR FACTORY.

But, by all odds, the largest amount of sugar produced is made from the sugar-cane, which grows in nearly every semi-tropical or tropical country of the world. Conditions in the East and West Indies are especially favorable to sugar-raising, not only because the sugar-cane grows there in great perfection but because the work of harvesting it and extracting the sugar is particularly adapted to the rather lazy laborers of those countries. It is rough work, that pays well for a short time every year, and that suits tropical laborers better than working long hours all the year round. From Trinidad alone about two and a half million dollars' worth of sugar is exported in a year, and the island has only about two hundred and fifty thousand inhabitants; this means that, on an average, every person makes $10 worth of sugar, besides what is used on the island. And when you know how many different things have to be done to sugar-cane to make one pound of sugar, and how many pounds of it $10 will buy, you can see that one of the main occupations in Trinidad must be sugar-making. In Cuba, about half a million acres are planted with the sugar-cane, from which they get more than sixty-five millions of dollars' worth of sugar annually.

The United States produces seven hundred and seventy-five thousand pounds of sugar-cane a year, of which seven hundred and fifty thousand pounds are made in Louisiana. Porto Rico exports about fifteen million dollars' worth of sugar and molasses; and sugar is also sent from Hawaii and the Philippines.

The lower part of the cane is richest in sugar, which is extracted by grinding the cane in mills that are often very rude and old-fashioned. When the cane has been put through the mill twice, the juice is treated with a little lime, or sulphuric acid, so that it will not ferment; for, in that hot climate, if left alone, the cane sap would soon turn into a kind of rum called "tafia." After this, the juice is boiled down until it is rather thick, and poured into coolers, where, in the course of twenty-four hours, the sugar-crystals form in the molasses. This makes what is called raw sugar.

THE GREAT SUGAR REFINERIES OF TODAY.

The Venetians were the first to refine sugar, but it was not commonly done until about the sixteenth century. The hand methods used were very crude and were not much improved until the machinery of a modern sugar refinery was developed. The process is comparatively simple, but the machinery is highly specialized. The raw sugar, which is something like brown sugar, is mixed with hot water, and the syrup is filtered through a great many double bags, and then through charcoal. One might suppose that it would come out of the charcoal quite black, but when it runs from the great cylinders in which the pulverized charcoal lies, it is perfectly colorless. Then it is boiled down and crystallized again. The pieces of white sugar are finally put through grinders which make what we called granulated sugar, or the finer sugar called confectioners' sugar; or they are cut into cubes of loaf sugar. It is interesting to know that, when first made, refined sugar was considered a great luxury and eaten much as we eat candy.

A BLACK HEN, WHITE SUGAR, AND AN OBSERVANT MAN.

There is a pretty little story, by the way, that explains how it was discovered that brown sugar could be made white by putting it through a dark filter. According to this tale, we owe it all to the humble hen, which, one would think, had already contributed more than her share to human progress. It seems that this historic black hen, scared from her nest, got off her beat, as hens will do—you never can tell where a hen will strike in, anyway—and, in her erratic course, ran frantically, first through a mud-puddle, and then plump across a pile of unrefined brown sugar. The story does not record the language used by the workmen or what became of the revolutionary hen; but one man, who observed instead of swore, noticed white tracks in the sugar wherever the black feet had flitted. And the era of white sugar was on—thanks to a hen, frightened out of her wits, and a man who kept his wits instead of losing his temper.

SUGAR OF COURSE SUGGESTS CANDY.

One of the most natural, as well as delectable, uses to which sugar is put is candy-making; and candy, through its association with refreshing experiences, is a pleasant subject to read about as well as a delightful article to eat.

The art of making any kind of sugar-candy, whether the candy is made in a saucepan on the kitchen stove, or in an enormous kettle in a factory is the same: The sugar is dissolved in water—a pound of sugar to a pint of water makes what is known as "stock syrup"—and, as it begins to boil, any scum that rises is carefully skimmed off. It should be boiled for a few minutes, covered, to dissolve any crystals on the sides of the pan. The whole kettleful will be ruined if it is allowed to boil a few seconds too long, and if the candy is being made for sale, it will not do to trust to the simple tests to which we subject the molasses candy that is made at home.

KEEPING IT JUST ABOUT HOT ENOUGH.

In the wholesale manufacture of candy nowadays, gas is usually used under the kettles, because by no other flame is the heat kept at so even a temperature. Candy-making being a very exact science, it is very important to know exactly how hot the syrup is at every single stage of the delicate process. Therefore the most important item in the list of things-to-make-candy-with is the thermometer. This is made of brass, and is not like the ordinary thermometer, because that only runs up to 110 degrees, while the candy-thermometer has a scale of 400 degrees. The different degrees of heat are called Pearl, Thread, Soft Ball, Hard Ball, Crack, Hard Crack, and Caramel.

FROM PEARL TO CARAMEL.

When the boiling syrup is at a heat of 220 degrees it ''pearls,'' and at 235 degrees it ''threads.'' You will easily see the reason for these terms if you watch the way boiling sugar behaves the moment it is getting ready to ''candy.'' When it becomes stringy and begins to ''thread,'' it is nearly done. At 240 degrees it will roll into a soft ball between your fingers, if a little of it is dropped into ice-water; and this is the point at which ''Fondant'' is made, which is the foundation for most of our cream candies. At 250 or 255 degrees comes the ''hard ball.'' At 280 degrees it ''cracks'' or crunches between the teeth when chilled in water, and 310 degrees makes the ''hard crack,'' the candy which is used for the shells on candied almonds, or for rock-candies. Last of all, at 380 degrees, comes the caramel. If the syrup boils above this point, it will be spoiled.

OTHER HELPS TO CANDY CULTURE.

The candy-maker can hardly work without a marble slab, for it is cool, hard, and smooth, and suited to the moulding of any sort of candy. Wooden spoons of a peculiar flat shape, called ''spatulas,'' are used for working the candy, and there are trays of various shapes. Another bit of machinery is the ''saccharometer,'' which tells just how much sugar is in the syrup, so that the confectioner knows how much more he must add for any candy he desires to make. Candy-bars are handy little steel bars, arranged on a marble slab, to mark off space for a sheet of toffee, or any other candy which is poured out to cool. Hair-sieves are used for straining, and dipping-forks are made to hold candies that are to be coated with chocolate, or fruits or other candies that are to be covered with sugar. For moulding peppermints and such candies, ''cream rings'' are used, which look like fairy muffin-rings.

MAKING CANDIES LOOK GOOD.

Candies are dyed many different colors to tempt the pocket-book through the eye. As a rule, white or colorless candy is more wholesome, but the fact that a candy is colored is not necessarily a reason for refusing it. Green used to be considered invariably poisonous, as arsenic in some of its forms was used as coloring matter; but a green tinge can now be given with harmless spinach. Beets may paint confectionery red, and saffron tints it with the color of gold.

THE HORN OF SUGAR PLUMS.

In old story-books you will sometimes find mention of ''a horn of sugar-plums.'' A hundred years ago there were no such things as paper bags, and candy-boxes had not been thought of. The candy-shop man took a sheet of pretty paper, twisted it into a horn like a cornucopia, tucked in the end, and tied it with a colored ribbon, sometimes further beautifying the horn with a gay picture. This cute little package is now seldom seen except at Christmas time, when it blossoms out into a dainty decoration for the Christmas tree.

Boxes are now favorite candy carriers, made in different shapes and often beautifully decorated. A "box of candy" is quite likely to be as acceptable a present as can be given to a friend.

LOOKING INTO THE WORLD'S CANDY WINDOW.

In all parts of the world, and for many centuries, sweets in some form have been eaten. If we could get them all into one great window, we should see many strange concoctions—some that would tempt out of our pockets every penny we possess, and others that we probably wouldn't have at any price, but that were just as inviting to the children of other days as your favorite candy is to you. They have all made somebody's "mouth water" at some time.

In boxes of mixed bonbons you will find a few little bean-shaped hard candies covered with silver foil, which are called "dragees." This is the oldest kind of candy that is made, and is named after the Roman confectioner, Dragius, who first made it. Nearly all candies were hard candies until about forty years ago, when the French cream candies began to be sold. Cream candies suggest chocolate candy, which is made from the kernel of the cacao nut. Pure cocoa and white sugar are ground together between heavy granite rollers into a fine smooth paste, to make a cake of sweet chocolate.

There are a good many nut and fruit candies which come to us from the East, where they have always been served to the luxurious ladies of the harem. Turkish Delights, stuffed dates, marchpane and nougat all probably came back from Saracenland with the Crusaders. Marchpane is one of the old confections; it was made by German, Dutch and English housekeepers hundreds of years ago, of pounded nuts, honey, with a little orange-flower water added to keep the nuts from being too oily. Nougat is made of white of egg, pounded almonds, and honey or glucose.

Lozenges have a history which goes back into the eighteenth century, and the word is a good deal older than that. In the Middle Ages, extravagant praise of any one by a minstrel who hoped to be paid was called ''losenger,'' and, after a while, the praises found on tombstones were called ''losengers.'' As time went on, the tombstones in cathedrals and churches were set so closely that they were mere diamond-shaped slabs, and anything cut in that shape was called a ''lozenge.'' Then French and Italian cooks, who made frosted cakes in large flat sheets and cut the sheets into diamond-shaped or domino-shaped little cakes, took to calling those ''lozenges,'' and finally, the first confectioner who made hard candies in the same way naturally called them lozenges, as they are called to this day.

One of the oldest of the English candies is barley-sugar, which has nothing to do with barley now, whether it formerly did or not. Nearly a hundred years ago, Tringham's, on Holborn Hill, was a great place for this candy, which was made in full view, poured out on hollowed marble slabs. Lemon-drops, too, have been made ever since sugar-boiling began, and toffee has been loved of English schoolboys since Tom Brown's day.

Some of the old names for candies have almost been lost, though we may still have the candies. Children about Boston used to think there was nothing like ''Salem Gibraltars.'' These were rock candies, flavored with lemon, and made at Salem, Mass., soft when they were fresh, but hard as the rock after which they were named, when they became stale. Taffy gets its name from the fact that it is made from molasses—tafia being, as we have mentioned, a West Indian name for cane-juice. Treacle is an English name for molasses, and lollipop is an English name for a kind of taffy. Marrons glacés are Italian chestnuts or "marrons," coated with sugar. Toffee in England always means molasses candy; only sugar candies are called candy there. Sugar-plums are any small, round bonbons. "Comfits" are fruits and seeds coated with sugar, and often are used as a sort of mild medicine, like horehound drops and licorice.

The candies which are pulled seem to have been invented in the North. In a southern latitude, molasses candy-making, except in the cooler part of the year, would be sticky business, and so would eating it; but in the clear, cold northern air the candy that can be crunched is particularly toothsome. And the candy-pulling parties are an experience that ought not to be missed.

CANDY AS DECORATIONS.

Making candy in the shape of people, houses or animals is a very old trick. Spun sugar has been used for decorating cakes and preserves for a very long time. It is made by whisking the thick syrup with an oiled whisk back and forth between two pegs, such as rolling pins fixed at the edge of the table, until it is all a mass of spider-webby threads. When these dry and harden, they can be sorted out and made into baskets and other decorations. The old-time confectioner was also a fancy baker, and one of the regular features at great banquets in the fourteenth and fifteenth centuries was what was known as a "sotelte" or subtlety—a group of figures built up out of pastry, jellies, and candies like a modern wedding-cake, and usually having something to do with the person who was to be honored by the feast. At a banquet given to an archbishop, for instance, there was a "sotelte" representing his patron saint, several angels, and himself, brought on for a sort of glorified dessert.

CANDY AND LAUGHTER GO TOGETHER.

We find the laughter-loving Italians on their carnival days pelting one another with handfuls of tiny, round, hard colored candies, or ''confetti.'' As time went on, plaster imitations of candies were used for the pelting, and these are now called confetti; but one may still, at an Italian fiesta, see real candies flung into a lady's lap, as she sits on her balcony or in her carriage.

WHEN CANDY-MAKING CAME TO NEW YORK.

One of the earliest confectioners in New York was a French nobleman who was exiled from France after the Revolution. He was the Count de Singeron, and helped to defend the Tuileries against the mob, but when he reached this country, penniless, there were so many other exiles ready to give lessons in French and dancing that, finding some candy he made for a friend's child very popular, he concluded to be a confectioner. He was the first confectioner in this country to decorate wedding cakes with garlands of candied roses, Cupids, and other charming devices in candy and frosting; he used to make marchpane modelled like the front of the Tuileries, and everything he did was as artistic as if he had been working in marble or alabaster instead of in sugar.

THE DEFT FRENCH AND THEIR DAINTY CANDIES.

It was the old-time Italian and Roman cooks who first taught the French the art of candy-making, way back in the days when the Roman legions camped in Gaul. No one has ever excelled the French at candy-making, or any other business where deft fingers, artistic ideas, and love of perfection are needed. Our prettiest candies are nearly all modelled on French bonbons, and the fashion of putting them up in dainty boxes also comes from France.

CHAPTER XXI.

Tea.

WHEN "TEA" WAS "TAY."

IN former days tea was called "tay," which is nearest the Chinese word "tcha"—which sounds Irish, but isn't. In the early years of the East India trade, we find one merchant writing to another to send him a box of "chaw." That again is misleading; he was not asking for tobacco, but tea.

THE NATIONAL DRINK OF THE ENGLISH.

A traveler might truthfully say that the only drink which is a daily habit in every part of the world is tea. Not only do the English, who go everywhere, drink tea at least once a day, but it is the national drink of China, Japan and Russia, and is largely used in the United States. In England each person consumes, on an average, a little more than six pounds of tea in a year,—nearly six times as much as an American. If you notice how small a part of a pound of tea is needed for a cup, you will have some idea how many cups of tea English people find necessary to their comfort. But, strange as it may seem, tea was not known in England until about two hundred years ago. The first tea came to Europe in 1610, and cost about $4 a pound; the first large importation of it to England was in 1678, when over four thousand pounds were brought from China. It took several years to dispose of that first cargo, and a hundred years to cultivate a universal tea-drinking habit. When it finally came into common use, many people fairly lived on bread and tea, which was, to say the least, not a very nourishing diet; and Dr. Johnson boasted that he drank his by potfuls, not by cupfuls, and often imbibed twenty-five cups at a sitting.

TEAS AND TEA DRINKING OF VARIOUS NATIONS.

The first tea in Japan was used by Buddhist monks who needed a drink to keep them awake during their long services. Japanese tea is very stimulating, but not much of it goes outside Japan. The common Japanese drink is green tea, which is made of tea leaves quickly dried, and is not generally as choice as the black teas.

Ceylon and India produce tea nowadays; the first plantations were started in 1840, but their tea is not as choice as the best Chinese kinds.

In Thibet stewed tea is a national dish; it is cooked with fat, salt, flour and milk until it is like porridge, and eaten cold. In Siam they chew it, and in Burmah they make it into a sort of syrup with sugar. Pickled tea is a Russian delicacy.

Some of the best tea is said to be made in the Baikal mountains, on account of the purity of the water, which will make excellent tea even of an inferior kind of leaves.

An odd way in which tea is used in Siberia is in the form of tea tablets. If one is taking a long ride in freezing air, where it would not be possible to make a cup of tea, one of these tablets can be put in the mouth with a lump of sugar, and the effect is refreshing. Cups of compressed tea have been made, which can be filled with hot water and will last from two to six months, just enough of the tea soaking off each time to make one cup.

BUT CHINESE AND TEA ARE THE TRUE PARTNERS.

The Chinese, however, are the great tea-drinkers. China consumes two billion pounds a year, about four times as much as all the rest of the world put together. Tea is the cheapest drink in the world, just as rice is the cheapest food; and tea, rice, and fish feed China and Japan.

Nobody knows how long tea has been used in

China, or where it first came from, but it grows wild in Assam, and it is mentioned in Chinese poetry as early as the eighth century. In its wild state it is a shrub, or even a tree in southern climates, but, when grown in a tea plantation, it is cut down so as to make it branch out as much as possible. In most Chinese estates the tea-shrub is planted anywhere that it will grow and in corners not used for rice, which is the main crop, although there are regular tea-plantations. It is related to the camellia, and has white flowers which generally drop off without going to seed. If you wish to see what a tea leaf is like you need only soak a pinch of tea in hot water until the leaves unroll, when you will see them more or less broken, or as they grew on the plant.

TEA PICKING.

There are three tea-picking seasons, but only one kind of tea-plant; the different kinds of tea, of which there are several hundred, all depend on the time of picking and the way the tea is handled when picked. When the shrub, planted from a cutting, is in its third year the leaves are fit to be picked, and the first picking, of the youngest and most delicate leaves, takes place in February or March. Tea known as Pekoe is made of these leaves, which are covered with a soft white down called in Chinese ''pakho.'' The Imperial tea of Japan, and the ''virgin'' tea in China, both come of this first picking. In Japan, the picking of this tea is sometimes done with thin gloves on the hands, by laborers who have been careful not to eat any coarse, strong-smelling food for several days. The best Chinese tea comes from near Nankin, but it is grown all over the country, even small farmers having as many tea shrubs as they can plant.

The second picking occurs later in the spring, according to the climate, and the third picking is in June. The last picking provides the coarsest and poorest tea, because the leaves by that time are large and rank.

One person can pick from ten to fifteen pounds a day, and one plant will produce about a pound of leaves; but it takes seven pounds of the green leaves to make one pound of tea. Then the leaves are culled over and the youngest and tenderest selected, but the cheaper grades, and finally the stalks and refuse leaves, are put aside for the tea the common people drink. The best goes to market.

TEA DRYING.

After the leaves are picked and sorted they are taken either to the public drying-house or to the room where the tea-planter has his ovens, and dried. In a drying-house you will see from five to twenty small furnaces, about three feet high, with a large flat iron pan on top, bent up a little on the side over the mouth of the furnace, on which the tea leaves are put and continually stirred—usually with the hands. When they are withered, but not dried, they are put on a long low table covered with matting, around which the workers sit. Some fan the leaves while others roll them, and sometimes the leaves are cooled and heated two or three times, the pan each time being less hot. "Fichi" or Imperial tea is dried without being rolled at all, being made of the tiny leaves and leaf-buds. After the tea has been kept for some months it is dried again, over a gentle fire. The common tea is kept in earthen jars, the finer sorts in porcelain, and sometimes the different sized leaves are separated by sifting.

TEA CULTURE OUTSIDE OF CHINA.

Several experiments have been made in raising tea outside the old tea countries of the East, but it will not grow in a cold climate, though the Duke of Northumberland managed to raise, in England, a tea plant that flowered, and there are a few plants in Kew Gardens. And, about 1890, a tea plantation was started at Pinehurst, S. C., which has prospered; and the Japanese have raised some tea in California. At Pinehurst tea has been grown under cocoanut matting, which gives the leaves a bluish color. There is only one other place where this has been done, and that is in Japan, where the tea intended for the Mikado's family is raised in this way.

THE TEA-CARAVAN AND THE STEAMSHIP.

Commerce in tea created great caravan routes through Asia, that have been in use for hundreds of years, but are being abandoned with the coming of modern methods of transportation. The caravan of old was a picturesque sight. Sometimes as many as fifteen thousand camels traveled together, all laden with tea, forming a line that stretched out for twelve or fifteen miles. There were some advantages in the ancient modes of travel by land, for it is found that, as soon as tea has to take a sea-voyage, it is prone to deteriorate. For this reason, the very swiftest steamships obtainable are used in the trade. When it reaches the United States, and this is true of many other countries, as well, it has to pass inspectors or tea-tasters employed by the Government; and only tea which comes up to a certain standard is allowed an entrance.

A CURIOUS FACT.

Some tea merchants have given a great deal of study to the question of blending tea, and many popular kinds of tea sold in this country are a blend, or mixture of several of the Chinese kinds, and the curious fact came to light in these experiments, that a blend which would suit one district would not suit another at all, because of the difference in the water in "making tea."

''MAKING TEA'' AN ART.

There is a knack—an art—in preparing a serving of tea—''the cup that cheers, but not inebriates''—that can be acquired only by the most careful attention to certain principles. Tea is so delicate an article, so easily made an unpleasant if not actually harmful drink, that it must be handled with corresponding tact.

THE TWO CHEMICALS IN TEA.

Tea contains two chemicals, thein, which is stimulating and wholesome, and tannin, which is neither. If made as the Chinese make it, either by pouring boiling water through a strainer in which the leaves are put, or by pouring it on the leaves and drinking the tea at once, the tannin stays in the tea leaves and does not get into the drink at all. But if the leaves are soaked more than five minutes the tannin gives the tea a bitter taste which is a sign of poison. That is why the second cup of tea, from a teapot in which the leaves have been left to soak, is never as good as the first. Good tea-makers always throw away the old leaves before making fresh tea, and use only freshly boiling water. Only the purest water should be used in making tea, and the tea should be chosen because of its taste, not on account of what some people call the ''twist,'' that is nothing but the way the leaves happen to be rolled, and has nothing whatever to do with the quality of the tea.

THE QUESTION OF MILK AND SUGAR IN TEA.

The Chinese, of course, use neither milk nor sugar in tea. A very old Chinese fashion used when tea was first introduced in China was to cook the tea with spices, sugar, orange peel and some other things, and make a sort of syrup of it; but for many hundreds of years the Chinese and Japanese have used tea just as they do now, perfectly clear, and not cooked at all, but made by steeping the leaves about five minutes in freshly boiled water. In Russia, the first country in Europe to use tea, it is always taken from glasses, not cups, with a slice of lemon, and the sugar is held in the mouth while drinking. It may be that we get our fashion of adding milk and sugar from the fact that when it was first brought to England it was cooked as a sort of broth or porridge—and it would surely need both milk and sugar to make it palatable then. At any rate, no tea-drinking country except England and America takes tea in that way.

TEA AS MONEY.

There are places where tea is used as money. One is Thibet and another is the region of the tea-caravan road through Siberia to Russia. For this use, and for use in Siberia and Russia, brick-tea is made. The tea is compressed into a solid brick worth usually two taels, or about $2.25. This brick is so solid that Russian officers traveling in Siberia often use it for a writing-desk; it will even hammer a nail into the wall. The test of a brick of tea is to put it on one's head and try to bend it; if it bends it is rejected. When the sum of money is so large that the bricks would make too heavy a load, the Chinese, who do most of the trading in that region, use the more valuable teas, putting them in little white transparent goatskin bags holding from one to three ounces. Some of the tea thus used is worth $200 a pound. Its leaves are about an inch long, and bronze or nut-brown in color. A very few American tea-merchants have some of these costly teas in glass jars, where they can be looked at for nothing.

GOING BACK TO CHINA, WHERE WE STARTED FROM.

The Chinese ''virgin'' tea, a very fine oolong, is used at weddings in China, and is really part of the ceremony. The leaves of this delicate tea are tied with silken threads in tiny bundles, and one of these bundles is held by its silken tie in a crystal cup with handles, and hot water poured over it. Then the leaves are removed and hung for two weeks in vinegar, to be used later in making tea-salad, a very choice Chinese luncheon dish. Tea is occasionally made from tea flowers, but it costs from $60 to $80 a pound. And there are some kinds of Chinese tea that are worth $100 a pound. These are bought by the wealthy Chinese as gifts, and it is quite common for one rich Chinese to send a $10 a pound gift package to a friend. The packages themselves are very beautiful, the boxes being made of lacquer, glass, bamboo or silk, cunningly decorated.

CHAPTER XXII.

Salt.

A UNIVERSAL CRAVING.

SALT is one of the few things that the human race cannot do without. To be sure, there are a few savage tribes in Africa who, it is said, do not salt their food, but they live in a place where the water is saltish, and get their salt rations in that way; on the other hand, in some parts of Africa a child will suck at a lump of salt as though it were sugar.

Salt goes into nearly everything we eat—that in our bread, for instance, amounting to about two ounces a week. So insistent is the human system on having its proper measure of salt that one of the worst punishments which could be inflicted on a criminal in the Middle Ages was to keep him in a cell where he was fed on food cooked without salt, and given rainwater to drink. This would kill him in a short time.

Cattle and most animals are fond of salt and cannot keep themselves in the best condition unless they have access to a regular supply. The "salt licks" still to be seen where salt came to the surface in the form of rocks or salt springs, attest to this universal salt-craving on the part of animals.

SALT IN HISTORY.

Salt is very intimately associated with ancient history, for the Roman soldiers were paid in salt—salarium—from which we get our word "salary." Henry III destroyed the salt works at Droitwich so that the Welsh, against whom he was making war, should not be able to get salt. And the salt tax was one of the causes of the French Revolution. Salt in the seventeenth century in France costs thirteen sous a pound (about four times as much as it does today), and every family was required to buy seven pounds a year for each person over seven years of age. This salt could not be used for anything but the pot and salt-cellar, that is, for cooking and the table. If a farmer used any of it to salt down pork, he would lose the pork and have to pay a fine; the fisherman could not use any of the precious seven pounds in salting fish; all that salt had to be bought in addition. No one could make salt for himself; cattle must not be driven over the salt marshes; and, if any one was found using really fine salt, there was trouble, because the salt authorized by the government was adulterated. The system was carefully arranged to compel the people to buy as much salt as possible at the king's prices. But you cannot make people pay more in taxes than they possess, and, in some parts of France, it came to such a pass that nearly everybody who was not a Government inspector was smuggling salt. Wretched people who had nothing to lose made their living in that way. Dogs were taken across the border, loaded with salt, and kept hungry, so that they would scamper straight home. And all these experiences gave the French language some keen proverbs. To this day, when a Frenchman has been cheated outrageously in a trade, he says he has ''been salted.''

SOURCES OF SALT.

An article so universally used as salt should be found in all parts of the world; and such, indeed, is the case. There are three sources from which it is obtained—sea-water, brine wells or lakes, and mines or salt-beds.

The first salt-making, probably, was by the evaporation of sea-water, which is accomplished by exposing tanks of water to the action of the sun, or by boiling the water down. Salt is still laboriously obtained in this way along the southern coast of Europe and Asia, but the salt is not very good. Moreover, it is a long and tedious process to extract salt from sea-water, for there is only 2 per cent. of salt in it; while the ordinary brine wells and lakes contain 25 per cent. or more, and in salt mines, and where the solid salt is dug out of the earth, it is almost pure.

NATURAL BRINE.

Where wells of brine exist, the brine is pumped up to the surface; but there is a story of brine-pits at Droitwich and Stokes that were worked in the time of the Romans through borings a hundred and seventy-five feet deep. If the pumps stopped, the brine would rise to the surface and overflow. The largest salt-springs in the United States are near Syracuse; they are many miles in extent, and the supply is said to be practically inexhaustible. There are other extensive salt-springs in the United States, those at Warsaw, Mich., being especially rich.

DOWN IN A SALT MINE.

Salt mines are distributed all over the world and in many countries. When salt is mined it is nearly pure, because, it is supposed, these mines are deposits made by some inland sea, ages ago cut off from any outlet, and the rains of the centuries have washed down upon the salt and made it clean, while, as it was shut in by layers of rock, it was not washed away. Near the Dead Sea there is a good deal of salt mixed with gypsum and other mineral matter, which has been so washed out that it has "lost its savor"; probably it was this salt which the Bible mentions. Of course, pure salt such as we use on the table cannot lose its flavor, because, if water were poured on it, it would vanish; but the impure salt used in Palestine might lose all its saltiness and be mere dirt.

The most famous salt-mines are in Eastern Europe. Those found at Wielicza, a town of about six thousand people, near Cracow, are so wonderful as to merit more than a brief mention. They have been worked for hundred of years, as have nearly all the salt-mines of Europe. When you go there, you are taken down more than two hundred feet before coming to the real mine, which has been called "a world of salt." Rooms, halls, corridors have been hollowed out there. One hall, one hundred and eight feet long, is like a Greek theatre and enough salt has been taken out of it to supply forty millions of people for a year. There is a lake, four fathoms deep, to be crossed in a boat. There is also a Chapel of St. Anthony, with an altar, and statues of various saints, looking as if they were carved of black marble, but really all salt. The damp air has set little streams of water running over the statues, and when Bayard Taylor was there, he reported that St. Lawrence had deeper furrows on his back than could have been made by any martyrdom. About one thousand five hundred men work in this mine, and a million and a half hundred-weight a year of salt comes out of it. The mine was first worked in the twelfth century, and it is thought that it cannot possibly be used up for at least three centuries more.

THE "WICH" IN NAMES OF ENGLISH TOWNS.

The best salt, and the greatest amount of it, is produced in English salt-mines. The salt beds at Norwich in Cheshire, for instance, are a mile and a half by one thousand three hundred yards in extent, a hundred feet thick, and about seventy-five feet below the surface. They were discovered in 1670 while a shaft was being sunk for coal.

Wherever you find an English town with a name ending in "wich"—Norwich, Droitwich, Nantwich, Middlewich"—it means, "Here are, or were, salt works." Norwich is built over a salt mine. This has the curious effect of making all the walls and buildings crooked, for the underground streams, where the water is constantly soaking through the ground, dissolve just enough of the underground layer of salt to keep the earth-level changing from year to year. One cottage has sunk so that what were the second-floor bedrooms are now sitting-rooms on the first floor. But, as Norwich was known as the "Black Salt Town" away back in the time of the ancient Britons, its folk are used to shoring up their cottage walls and sills, and do not seem to mind. Cracks open in the walls and the ground, and on a still night you can hear the bricks "grumphing," as the people say; but though the shifting of levels makes a good deal of fuss and trouble it does not come suddenly enough to be really dangerous.

SATURATION OF SALT.

Where the mined salt is impure, it is put in water till the water is "saturated," that is, till it has taken up as much salt as it will dissolve, and then the water is ready for evaporation. In some mines, especially in Bavaria, where the salt is mixed with gypsum, water is run through the soil, becomes saturated with salt, and is then drawn off. The salt-laden water is then carried in pipes to the evaporating works, often many miles distant. These pipes sometimes have to cross mountains, and hydraulic machines are used to force the water upward. The mountain brooks and streams furnish power to run the machines, and altogether it takes a great many ingenious devices to get that brine to the kettles.

THE EVAPORATION PROCESS.

Brine from wells and springs, or mined salt which has been saturated, must go through the process of evaporation. This is accomplished by boiling in evaporating pans, which are much the same as they were when the first monks came to Britain, only that then they were of lead, ten feet square, and now they are of iron, one thousand five hundred feet square. When the boiling begins, a scum rises made up of the impurities in the brine, and after awhile the salt-crystals, little four-sided, irregular pyramids, begin to form. When the crystallizing is finished, the salt is usually baked in an oven to render it as dry as possible.

Salt made entirely, or almost entirely, by evaporation in large tanks, under the heat of the sun, is called solar salt, and is in large crystals. This is sold mostly for packing fish and meats, for which it is better than fine salt, because it dissolves slowly and keeps the meats from being packed too closely. When fishermen from Gloucester and the Maine coast go to the Grand Banks for cod, they take with them this coarse salt, and, as the fish are caught, they are salted and packed in the hold. When a fisherman is ready to start for home, he says he has ‘‘got all his salt wet.’’

KINDS OF SALT.

There are several grades of salt on the market in the United States: Rock, solar, common fine, common coarse, and dairy—the latter used especially in the manufacture of butter and cheese.

PART III.

DISCOVERIES AND INVENTIONS CONTRIBUTING TO THE ADVANCEMENT OF KNOWLEDGE.

CHAPTER XXIII.

The Great Paper Making Industry.

ONE OF THE ESSENTIALS TO PROGRESS.

PAPER is one of the substances so familiarly known and used as to be accepted without comment, as natural as the air, the water and the sky. Yet, paper, like glass, is not a natural product, and is the result of either successive inventions or adaptations. Perhaps it would be better to say that paper is the result of a great need. With movable type and the printing press, paper takes equal rank as being one of the prime essentials to progress in all forms of human work and endeavor.

WHAT THE DICTIONARY SAYS PAPER IS.

Accurately described, paper is a substance which the scientists call ''cellulose,'' as we now see it. It is defined in one dictionary as ''A material consisting of a compacted web or felting of vegetable fibres commonly in the form of a thin, flexible sheet.'' Another definition suggests also how paper is made, using words: ''Paper is a thin tissue of vegetable fibres (rarely of woolen fibres) resulting from their deposition on wire-cloth while suspended in water.''

LONG BEFORE PAPER—WHAT?

Books were made, documents were written, and written intelligence was passed from hand to hand, and, indeed, from century to century, long before paper was thought of. The sun-baked brick hieroglyphics of Egypt formed imperishable libraries. The Bible tells us that the Commandments were handed down to Moses written on "tables," that is, tablets, of stone. We know that the earliest religious teachings were written on skins, so treated as to be nearly white, and skins, under the name of parchment, are still used for receiving important writings.

WHAT THE WONDERFUL CHINESE INVENTED.

As usual, the wonderful Chinese began paper, as they also seem to have begun the art of printing. There is a record that the Chinese made paper from cotton in the second century before Christ. After the capture of one of their cities—Samarkand—early in the eighth century, by the Arabs, the knowledge of what paper was and how to make it was spread abroad. Paper from linen rags was first made in Europe in the fourteenth century, and the wonderful papyrus plant seems to have been the source of a form of true cellulose resembling paper, even earlier than these dates in Egypt.

THE PRINCIPLE THAT UNDERLIES PAPER-MAKING.

Paper made from vegetable fibres is really pure cellulose, whether the fibres are those contained in cotton or linen rags, in the wood now so much used, or in straw or any other vegetable material. An expert paper maker has thus set down the basis of paper manufacture: "The underlying principle in making all grades of paper is to first reduce the raw materials to pulp, to dilute the pulp so as to disintegrate the fibres, and then to reassemble them by quickly getting rid of the water and depositing the fibres in the form of a sheet.''

This principle applies today, as it did at the very beginning of paper making, whether paper be made by hand, in the smallest possible paper mill, or in one of the tremendous establishments turning out hundreds of tons a day.

HAND WORK OF LONG AGO.

At first paper was made by hand only, and in a very simple fashion. The rags which were the material for making paper were washed, bleached by something which would take out any color, and beaten until they were reduced to pulp. This pulp, diluted so as to look like nothing so much as somewhat thin milk, was kept in motion, and into it was dipped a frame of crossed wires, known as a mold. When this was lifted from the vat and shaken by a deft shift of both hands, the water drained out through the wires the fibres were assembled, and the sheet of paper still soft, flimsy and wet—was made. It was an interesting experience of the writer recently to make several sheets of paper under the guidance of a large manufacturer, who brought the material with him in a bottle and arranged for the hand production of actual paper from the liquid pulp.

THE GREAT MACHINES OF THE PRESENT.

But, as with other items of advance in the world, the introduction of machinery has been essential to progress. The invention of the paper-making machine stood in the same relation to paper-making as did the invention of the cylinder press to printing. Louis Robert, merely a clerk working for the great Didot firm at Essenes, near Paris, toward the end of the eighteenth century, devised what persists today, with many improvements and extensions, as the Fourdrinier paper-making machine. It takes its name from its introduction by the Messrs. Fourdrinier, in 1804, into England. It was eight years later when T. Gilpin & Co. set up one of the machines in the United States, not far from Philadelphia. The growth of paper-making may be judged by comparing the product of this first machine, of the value of probably $25 a day, in 1812, with the present estimated product of a half million dollars worth of paper daily.

THE RAW MATERIALS FOR PAPER-MAKING.

The raw materials used in paper-making in the United States may be broadly divided, so far as the source of cellulose is concerned, into two sections, one involving rags and the other wood. By reason of the great need for a cheaper material, and by equal reason of great improvements in the manner of reducing the cellulose found in wood to available pulp suitable for paper-making, wood is now most largely used. Yet rags are an essential and vital necessity in the making of the best grades of paper.

WHERE RAGS HAVE A REAL USE IN THE WORLD.

These rags are procured not only in the United States but come here from all parts of the world. There are many well known commercial grades, the designating names of which do not necessarily mean that the rags are what the name would indicate. For instance, ''Dutch blue cotton rags'' may have yellow and brown and red and green or any other color but blue included in a bale of them, but it is certain that they will be clean and of a good grade of cotton. The grade known as ''black stockings'' does not necessarily mean that other black cloths than stockings are not included.

As these rags are received in a paper mill, they are ''dusted'' in a large machine and then treated in the sorting room in such fashion as to remove all buttons, buckles, and foreign substances, in connection with the sorting into the various classes. A cutting or shredding machine reduces the size of these rags, and another duster takes out still more of the foreign matter before the rags reach the ‘‘rotary boiler.’’ This is a large, horizontal boiler in which the rags receive a treatment with live steam and lime water, which results in removing impurities and in at least beginning to take out the color.

The ‘‘washers’’—circular machines with mechanical means for ‘‘beating’’ the rags in cold water—further remove both color and impurities. From the washer the rags go into draining pits under the washing engines, where time and chloride of lime, or some other bleaching liquid, finally remove all color. As stored for several weeks in these drainers, the rags are called ‘‘half stock.’’

WOOD PULP AND ITS PREPARATION.

As most paper contains both wood and rag, it is desirable to follow the fortunes of the tree at this juncture. The logs, preferably spruce or poplar, come to the mill in five-foot lengths. It is said that at least three thousand acres per day are cleared of timber to feed the shredding machines, which chip up the wood into an available form for further action.

The chips are boiled in a great cylindrical receptacle, called a ‘‘digester,’’ for seven or eight hours, with steam at high pressure, and in the presence of what is known as caustic liquor, made up of caustic soda and lime. This treatment reduces the wood to available cellulose by removing the rosin and other ingredients which once went to make up the tree. From the digester the pulp goes into a washing engine, and then into a ‘‘bleacher,’’ where chloride of lime again serves to remove all traces of color, while the pulp is being beaten at the same time.

Incidentally, the caustic liquor here referred to is an expensive fluid, and if it was not possible to recover from it the soda which makes it efficient, paper would cost much more than it does now. The pulp mill therefore uses the "Yaryan machine," by the use of which about 85 per cent of the soda is recovered.

It is further interesting to note that it takes about three hundred pounds of wood to make one hundred pounds of pulp, and that two hundred pounds of coal are required to do the necessary heating.

Another incident in paper making, but an important one, is the necessity for a supply of perfectly clear water. A great paper mill therefore usually provides its own filter plant, and one of even moderate capacity will use each day as much water as a city of forty thousand inhabitants.

HOW PAPER IS MADE FROM PULP—RAG OR WOOD.

Putting together now, the two preliminary parts of the paper-making process we are discussing, we find that in the "beating engines" are assembled and finally combined the various materials required. A certain percentage of rag pulp, a certain percentage of wood in some one of its several forms, together with some rosin, clay, sizing and coloring matter, go to make up a mixture which is produced upon a carefully determined chemical formula. In this beating engine, which closely resembles the rag washer, the mixture is worked and rotated until it is quite smooth and of even consistency. From the beating engine it goes to what is known as the "wet end" of the Fourdrinier machine, where it is extensively diluted in a part of the machine known as the "agitator," which keeps the paper fibres in suspension until the mixture flows on to the screen upon which the paper is to be produced.

The Fourdrinier machine is from forty to one hundred and twenty feet long, and is provided with various interesting appliances. There is, for example, a magnetic separator, to remove any iron particles which may have escaped previous inspections. There is an interesting method for shaking sidewise the long woven wire screen upon which pours the thin fluid of pulp which is to be made into paper. The little side shake thus given does, on this great and rapidly moving machine, exactly what the side shake of the operator who holds a mold in his hand does to assemble the fibres in the process of hand paper-making.

Once the fibres are assembled as paper on this woven wire screen, through which the water is not only escaping by gravity but through which it is pulled by vacuum pumps, the rest of the process is concerned with the surface, the markings and the drying of the paper as it passes along to the ''dry end.'' The ''dandy roll'' is a small cylinder, covered with wires, which determines whether the paper shall have a smooth ''woven'' surface, or shall show the marks of the wire, so that it may be called ''laid'' paper. If the paper is to have a ''water mark,'' the letters or characters forming it are woven into the surface of this dandy roll, which impresses them into the paper as it revolves on the soft mass from which the water is escaping. At the dry end of the machine steam heated rolls remove the last of the water.

BOOK PAPER.

Paper is of many finishes. If it is intended to be used in the ordinary unillustrated book, what is known as ''machine finish'' paper is made, and it is practically completed when it comes from the machine. If a polish is required, in order to receive the impression of engravings, the paper is treated to what is known as a ''calendering'' process, by being passed through a set of partly heated cylinders of iron and compressed paper, or cotton, which exert considerable friction on its surface.

If the paper is to be finished as ''coated'' paper, such as is found in the magazines, books, and catalogues using many illustrations, it is rolled into reels without the calendering process, and is then transferred to a department of the paper mill known as the "coating room;" here is where the coating machine brushes into the surface of the paper a mixture of white English china clay and glue, after which the paper is again dried by being passed along ingenious rolls, which maintain it in long festoons in a temperature of about 120 degrees, and then finally calendered.

FOR THE DAILY NEWSPAPER.

Newspaper stock is completed on the machine, and there is in it little or no "rag stock." Moreover, for much of the paper used by the daily periodicals, the wood is not reduced by caustic liquor, but is merely ground up and beaten. It is for this reason that a specimen of the average newspaper exposed to the sun for several hours turns yellow and becomes brittle. The sun continues the chemical process begun when the wood was beaten, but arrested when the paper was finished.

WRITING PAPER.

Writing paper, on the contrary, contains little or no wood. In some cases writing paper of the higher grades is made only of new linen clippings. It is finished as it passes through the paper mill by having applied to it a "sizing" of glue and other substances, which gives it a surface suited to the pen. There are also various processes for "plating," or pressing, the paper, and for giving it special finishes by means of mechanical appliances of various sorts, which it is hardly practicable to discuss in this brief review.

HOW PAPER GETS ITS COLORS.

The inquiring reader will be wondering how paper is caused to assume various colors. For papers which have the same consistency throughout, the color is applied when the mixture is made in the beating engine. For what is known as "surface-coated papers," such as are largely used in labels and the like, the color is mixed with the coating and brushed on in the coating process.

READY FOR THE PRINTER.

Paper when made is stored in several ways. Usually the paper mill has on hand great rolls of paper of varying widths and qualities, from which it cuts on rotary cutting machines the sheets required by the printer, unless, indeed, the printer orders the paper in webs or rolls, for special machines. Newspaper is generally paper delivered in rolls, which run through the great printing presses they use, without hand labor.

The higher grades of paper are put up into bundles or "cases," after a very careful inspection. The inspection is accomplished by expert women, who handle every sheet and throw aside all that present any imperfection.

Much more might be written about special kinds of paper and about many variations in the process of manufacture. What is here set down gives, however, the essentials which relate to the separation of the source of cellulose into its component parts and to the reassembling of the fibers into that marvelous necessity—a sheet of paper.

CHAPTER XXIV.

Typesetting and Casting Machines.

A NEW AND WONDERFUL MACHINE.

THE story of the typesetting machine is quite as wonderful, indeed, as the story of the printing press. Its achievements have had almost as much to do with the growth and development of the printing industry, but these unfortunately are little known to persons not in some way identified with the printing business.

A MILESTONE IN THE HISTORY OF PRINTING.

It was in 1456 that Gutenberg's invention of movable type for printing purposes was announced to the world; and it seemed that from that time printed books and pamphlets would soon become the common heritage of the people for their advancement and learning. But the progress of the art was marked by many trials; and while type-founding or cutting was generally practised in England and most of the European countries twenty-five years later, it was not until 1822 that the first patent was obtained on a typesetting machine. This patent was secured in England by Dr. William Church, of Boston. As it was not practically successful, it may be said that for a period of four hundred and twenty-five years, types for books and newspapers and other varieties of printing, were set entirely by hand, for not until about 1885 was the first practical typesetting machine demonstrated successfully.

This achievement was one of the important milestones in the history of printing. It marked the introduction of new ideas in the conduct of printing plants and made possible the publication of certain kinds of books and newspapers that could not otherwise have been published. The Patent Office records of various countries show that, although upward of one hundred and twenty-five distinct patents of the basic principle of a typesetting machine have been recorded, not one quarter of them have actually been built.

As the art of type-founding was rapidly developed, type made for setting by hand could be obtained from the founders at very reasonable cost fifty years ago, and at that time inventors were striving to perfect a machine that would assemble automatically the different letters in a line, ready to print, by depressing the keys on a keyboard.

WHAT JOSEPH THORNE, AN AMERICAN, DID.

Joseph Thorne, an American, had been experimenting with typesetting machines since 1869, and in 1880 he obtained patents on a new machine for setting foundry type. Two magazines, each fifteen inches in diameter and containing ninety separate letters, specially nicked or grooved in front, were set up in a vertical position over the keyboard. When the key was depressed the correct letter would leave the channel in the lower magazine and was carried by a revolving belt to the assembling galley, and the words thus formed would run out in a continuous line. The upper magazine revolved and fed the type into the channels in the lower cylinders from which the type dropped when the key was depressed. The letters forming words were broken into lines of the required length by a second operator, or justifier. In 1898 this machine was remodeled and named the Simplex One-man Typesetter. This machine would compose with two operators about four times as much type as one man could set by hand. Probably four hundred of the Thorne machines are in use in different printing offices in the United States at the present time.

The two different types of machines in use today all over the world have very little in common with any of their predecessors in the basic principle of their construction or operation.

THE LINOTYPE.

Coming down to the machines that are in constant operation in every city, and in almost every country town, in this country and in Europe, we have first to consider the slug or line-casting machine as distinct from the machine that casts and sets ready for use assembled lines of individual letters. The slug is in reality a solid bar or line of type cast from matrices assembled in their proper order, and as delivered from the machine is ready for use to cast stereotypes or electrotypes, or to print directly from the face of the slugs.

This machine is called the Linotype. It takes its name from the solid line of type that it produces. It has been in use successfully in newspaper offices and commercial printing shops since 1885, and to Ottmar Mergenthaler, who was a German immigrant in 1872, then eighteen years of age, belongs the honor of inventing this machine which is at the zenith of its success at the present time. Mergenthaler was a watchmaker living in Baltimore.

The Mergenthaler machine of 1885 was put into use at a time when printers had wearied of the experiments of the previous fifteen or twenty years, and the new machine had practically no competitor. As was the case with most of its predecessors, the Linotype was first taken up by the newspaper, to which, with no more than two sizes of type of one measure in width to consider, the new type bar or solid line was especially attractive, since it could not be ''pied,'' or easily broken up; and this facility in handling was of the greatest importance where time in the newspaper composing-room counted for so much.

Since 1885 the Linotype has had no very serious competitor in the newspaper field. One might say that it is a machine especially adapted to newspaper work. It has speed, and sufficient flexibility in its scope to answer the none too exacting requirements of newspaper typography; and with its solid-line feature it appeals to the publisher who feels that this offers a great saving of labor and money in the rush and hurry of newspaper making.

It was in 1884 that Mergenthaler conceived the idea of assembling a line of matrices, or dies, each containing all the letters of the alphabet, and injecting into them the molten metal to form a complete line or slug of type. As it was impossible to correct errors as soon as discovered with this machine, he built in 1885 a machine which contained independent matrices, that is, the matrix for each letter was a unit, or separate. More than two hundred of these machines were built, sixty being sent to England. Not even this machine, successful as it was, was considered satisfactory by the inventor, for it had some objectionable features which were overcome in a new machine perfected in 1890. Many improvements have been made in the Linotype machine since then, until today, in the hands of competent attendants, it fulfils on plain reading matter most of the requirements of the modern newspaper and book-printing office.

THE OPERATION OF THE LINOTYPE.

The Linotype is very simply operated. By depressing a key on the keyboard the matrix containing the letter is released from the magazine and falls by gravity to a revolving belt which conveys it to the assembling point. When the matrices for the first and following words in a line are assembled, the operator touches the space key, which releases an expanding steel wedge, and when the line is full, or so nearly full that no more words can be admitted, the assembled line with the wedges between each word is carried to a position directly facing the mold and the wedges are pushed up, expanding the line to the desired width and of course increasing the amount of white space between the words.

The molten type metal, heated by a gas burner, is then forced into the mold, and the line when cast, drops into the galley at the operator's left. The matrices from which the line has just been cast are then elevated to the top of the machine, and each matrix or letter is deposited by an ingenious mechanism in its proper channel. Each of these matrices, or letter dies, is nicked, much the same as is the key for a lock, there being a different arrangement of nicks for each letter. The letter, or matrix, does not drop into the magazine until its corresponding nick is reached over the channel.

As the same matrix cannot be used twice in the same line, each channel in the matrix magazine must contain a sufficient number of each letter to be used in the longest line. For example, it would contain more "lower case" or small e's than any other letter as this is the most frequently used letter in the alphabet.

As the requirements of printing necessitate accuracy in the finish of any matter to be inserted in a type form, the Linotype slugs with the type characters on the printing surface are trimmed by knives on the bottom and sides. Just as soon as the lines of type or slugs on the galley are cool enough to handle they are ready to use, and can be made up in the form for stereotyping or locked up in a chase, or flat frame, ready to print.

Linotype machines can be equipped also with a style of matrix called "two-letter." This single matrix contains a Roman character and a black-face character, one over the other, and the operator can control the use of either, setting part of the line in Roman and the other part in the black-letter. In place of the black-letter italic type is sometimes used, especially in printing offices using the Linotype on book work.

In correcting the matter set by Linotype it is of course necessary to reset the entire line, as the slug or bar is solid and not even a period or a comma can be inserted. Well trained operators, however, make surprisingly few errors on plain work, such as newspapers and ordinary novels.

With a competent operator, the Linotype is capable of setting five thousand "ems" or from two thousand to two thousand five hundred words an hour. An "em" is the square of the body of any size of type. This would be equal to the work of five or six men setting type by hand. Of course, there are exceptional cases, and frequently in competition a speed of nine or ten thousand ems has been made.

THE "MONOTYPE" MACHINE.

There is another machine used largely in all book, job and newspaper printing offices, and this is called the Monotype, because it casts and assembles automatically, in lines composed to the proper width, individual letters instead of casting a solid type-bar or slug. In fact, this machine casts and composes type absolutely identical with new foundry type.

The Monotype system separates the two important operations of machine composition, that is, the work of the operator at the keyboard, and the casting and assembling of the different letters.

The Jacquard system of controlling any mechanism by means of a perforated ribbon, through which compressed air is passed, has been applied to the operation of a typesetting machine in the Monotype. Although commonly called the Monotype, the name of the inventor, Talbot Lanston, of Washington, D. C., is inseparably associated with this machine. His first attempt at a typesetting machine, involving the Jacquard system of paper-ribbon control, was made in 1885. This machine was not wholly practical, and many further experiments were made up to 1897, when the Monotype upon which the present machine is structurally based was perfected by Lanston and was successful from the beginning. A large number of these machines were sold, particularly to the important book and job printing offices handling the finer grades of book work, catalogues, railroad tariffs, and other kinds of intricate composition.

FEATURES OF THE MONOTYPE.

It was the single or individual letter feature of the Monotype that made it particularly valuable on this class of work, as all necessary corrections could be made by hand in the same way that a compositor would correct foundry type; and in the making up of books and catalogues in which illustrations were used the matter cast on the Monotype would be run over by hand so that cuts (blocks on which the illustrations are made), could be inserted and the width of the columns or pages changed without involving the use of the machine. These single letters, as cast automatically and justified by the Monotype, are never distributed in type cases like foundry type. As soon as the type has been printed from, or used to make plates, it is put in the melting-pot and melted over just as Linotype slugs are.

Since the Monotype keyboard is separate from the casting machine, it would be possible for the keyboard operator to perforate the paper ribbon in San Francisco and send this ribbon to New York to be fed into a casting machine there, and the type matter so produced for newspaper, magazine, or book would be letter-perfect in every respect with the copy originally used.

When the operator strikes the key on the Monotype keyboard two punches are raised by compressed air and perforate two holes in the ribbon, which is four and five-sixteenth inches wide.

The Monotype scheme of spacing and justification is very intricate but accurate. There are two rows of keys numbered from one to fifteen at the top of the keyboard, and as the operator has before him a calculating scale, which adds the total number of separate letters in each line, for the set or width of the face that he is using, the indicator tells him, when he reaches the end of the line, the justification keys that should be struck in order to add the proper number of spaces between the words and so fill out the line. When the copy is completed, the paper spool, which winds automatically, is removed from the holder and transferred to the casting machine, which produces the type.

The Monotype caster is a very compact and simple machine. It is about four feet high and weighs about fifteen hundred pounds. The caster is operated by a one-half horse power motor, and is furnished with compressed air to regulate the pin stops in the machine, which are controlled by the paper ribbon from the keyboard, and which present the proper matrix to the mold. It is supplied also with water to keep the mold cool and with a gas burner under the melting-pot. One of the main features of the casting machine is the matrix case, which is so small that it can be carried in the top coat pocket, its 225 matrices being arranged in a square exactly 3x3 inches. Each matrix is about half an inch high and .2 of an inch square. The die case containing the 225 characters being controlled by the air pins, and moved forward and backward by levers, centers the proper letter over the mold, below which is placed the nozzle of the metal pot, and the pump injects the molten metal into the mold directly under the matrix. The mold is changed for each body size of type used, but each one is equipped with a blade, which of course is movable so that letters of the different widths can be cast. The Monotype casts and delivers the type backward in the machine—that is, the last line perforated in the ribbon by the keyboard operator is the first line to be delivered from the casting machine.

In changing from one type-face to another with the Monotype, it is only necessary to remove the matrix case from its position over the mold and insert a new one, changing also what is called the wedge, which controls the width of the letters to suit the second type-face to be used.

The Monotype machine, in addition to composing all the common type sizes in use on newspapers and books, is equipped also with molds and matrices for casting job type, that is, the sizes from 14 to 36 point, which means as large as half an inch in size. These large faces are not used in composition or operated from the keyboard, a different type of matrix being furnished from which the letters are cast individually at the casting machine. Printing offices, equipped with Monotypes therefore, can make and cast their own type and distribute it in cases, just the same as they would do with the type they might purchase from the type foundry.

The speed of the Monotype is from four thousand to five thousand ems an hour on the keyboard, and from three thousand five hundred to four thousand five hundred ems at the caster. Like the Linotype, however, the Monotype keyboard has been operated continuously at a speed in excess of ten thousand ems an hour.

A FUTURE COMBINATION.

Since the Linotype casts a solid slug, which must be reset for correcting and which does not lend itself to hand manipulation in making up, and since Monotype work consists of two operations, we look forward to the eventual perfecting of the ideal machine, which may combine both the important features of the two machines that are now so widely used. This machine may be operated by one man, achieving an economical feature in this respect, and cast individual type as the Monotype does. With these two features embodied in one machine, the whole tendency of composition by mechanical methods would be towards the improvement of present typographic standards.

CHAPTER XXV.

Printing, One of the Greatest of Inventions.

THE CONVEYANCE OF THOUGHT.

BROADLY defined, printing as at present practised is the means whereby thought in word or in picture is duplicated with sufficient economy to be available to a large number of people. This definition will apply, whatever the process of printing. It will be seen at once that upon printing, therefore, as thus defined, has depended and now depends the progress of the world. Without printing to spread thought not only is social, moral, and religious progress impracticable, but business and economic progress as well.

No educational institution could exist many months if its supply of books were cut off by the abolition of the practice of printing. No great business could long persist if its use of many of the methods of printing were interfered with. Governmental functions, as practised in the world-around nations of the twentieth century, could hardly be continued without the turning of the printing press. The news of all the world, now brought to us every day, depends absolutely upon printing for its circulation. There would be little inducement to write great poems, interesting stories, or to tell of travel or adventure, or of the new findings of science, if printing was not at hand to give them wide publicity. It is said that the seventeen letters spelling the name of a certain widely used article were considered to be worth a million dollars each when the concern making the article was reorganized; and all this was created solely by the use of printing.

AN ART A THOUSAND YEARS OLD.

It is a common error to say that ''printing was invented'' by Gutenberg, Fust or Schöffer. Printing had existed long before the memorable fifteenth century, but its actual origin is lost in the mists of antiquity. It is definitely known, however, that the astute Chinese possessed, at least a thousand years ago, the ability to transfer impressions from inked blocks to substances much like paper.

But printing received its most important impetus when one or another of the German worthies invented or devised movable types, about the year 1457. With these movable types, which could readily be used over and reassembled into different word forms, it was practicable to print, without the vast expense previously required to engrave upon wood or metal, the characters of the printed page. There was, it is proper to say, no idea of developing the printing of books as a new art.

The actual idea was to make, by the use of movable types, at a much lower cost, duplicates of the great books, mostly religious, then being painstakingly written by hand. It is not at all improbable that the men who supplied the money to develop the invention saw the profitable possibilities of being able to make Bibles and religious manuscripts to sell cheaply, instead of the very costly hand written work.

The first printed books were not completed by printing only. Initials and headings were added by hand in the form of ''illuminations,'' exactly like those found in the books produced by the copyists and the monks.

PRINTING IN EARLY DAYS.

It is proper here to pause and to wonder at the perfection with which, in those earlier days, the art of printing—for it surely was an art as then practised—was carried on. It is not many months since one of the few existing copies of the first great printed book, the Gutenberg Bible, sold for $50,000. Its pages are clear and undimmed by the passing of time. Few modern books are so made as to be likely to be at all perfect in five hundred years.

Governments early took cognizance of the new art, and because of the supposed dangerous possibilities of so easy a means of duplicating the written words, printers were compelled to sign their products. Thus arose what was then known as the ''printer's mark,'' and is now known as the printer's imprint. The writer of these lines has great pleasure each day, as he goes about his typographic business, in looking at a collection in enlarged form of the ''marks'' of the earlier printers, ranging from that adopted by the first known printers—Fust & Schöffer—in 1457, down to the marks or imprints of the present day, as attached to worthy works by such great presses as those of Riverside, the University, DeVinne and others. That mark, it may be observed, was as much to locate the printer as it was an object of distinction, and so it serves in these days.

TYPOGRAPHIC PRINTING.

Printing from movable types is technically described as typographic printing. In this form the individual type has a raised face or surface, upon which ink is deposited, which, when removed to a sheet of suitable paper by applied pressure, constitutes the printed result. This is by far the most important form of printing. It makes all the newspapers, and about all books. It is the means of making magazines and of producing the vast flood of advertising matter. It is the cheapest and most rapid of all the printing processes—the daily newspaper is produced in a few hours, and is often printed at a speed of thirty thousand or more in each hour.

LITHOGRAPHIC PRINTING.

Lithographic printing differs in that there is not necessarily a raised surface from which the impression is removed to suitable paper. A stone, or in some cases, a sheet of zinc or aluminum, is used as the surface upon which designs, pictures, or words are drawn, or ''transferred,'' or otherwise imposed or lightly engraved, in a greasy ink. When a dampened roller or its equivalent is passed over this surface, that portion of the stone or metal plate which has not received the drawing or lithographic impression, is moistened, so that when subsequently a roller charged with printing ink is passed over the plate, the design only receives the ink, the dampened portion refusing it. The stone or metal plate then yields its impression to paper under pressure, substantially the same way as the type yields its impression.

Lithographic printing is used largely for commercial, technical, and art reproductions of a character not so easily practicable with the aid of movable types or upon the typographic press. By its aid have been made beautiful things in many colors. There being no limitation as to the fineness of line, or the proximity or interlocking of letters, various designs are produced by the skilful lithographic artist which it would be impracticable to make by movable types. The machines and processes involved are different from those which are applied in typographic printing, and therefore lithography is an independent trade. It is next in importance to typographic printing among the various branches of printing as a whole.

LETTER DESIGN IN MOVABLE TYPE.

When movable types were devised by the old German fathers of printing the aim was, as has before been indicated, to make the most efficient imitation of block-printed or hand-inscribed books. Type-design, therefore, was not at all free or for any original purpose. The old punch cutters followed as closely as they could the so-called ‘‘black letter’’ used in the ancient books.

As printing from movable types emerged from the purely imitative stage, some attention began to be paid to letter forms, and what we know as the Roman character gradually supplanted, especially in Italy and in England, the black letter. This is not the place to go into the history of letter design, but it may be safely suggested that the old masters of printing worked faithfully, thoughtfully, and with the high ideal before them of creating such forms of letters, to be eventually cast into movable types, as would best convey thought. The types worked out by Aldus Manutius in Venice, by some great masters in Belgium and Germany and Paris, and particularly by William Caslon in England, have persisted to this day, and will probably persist, because they embody the ideal just mentioned, that of conveying thought in the best way.

TYPE HAS ‘‘FACES.’’

The ‘‘well dressed’’ printed page sets forth no peculiarities. It simply transmits thought with the least friction. Therefore it does not have a great variety of type-design displayed upon it. In the same direction the commercial work of printing, that is, the production of commercial forms and of various other items of printed matter not especially attached to the printed book page, have come to be regarded as requiring the use of but one ‘‘face’’ of type, in which there may be many available sizes.

Designs for new ‘‘faces’ of type are frequently drawn by expert draftsmen to a considerably larger size than the resulting type is expected to be. After the design has been approved, a set of pattern letters is drawn, from which, by use of an ingenious machine called the pantograph, the ‘‘face’’ in mind, that is, the particular size of the particular letter that has been designed, is drawn on the metal, preparatory to the cutting in soft steel of a so-called "punch." By the use of the pantograph the same pattern letter will answer for a number of sizes. An ordinary series of type, intended to be used for display work and not merely for page printing, like that in which these words appear, includes from thirteen to eighteen sizes.

From these punches, which are engraved on soft steel and then hardened, a "matrix" is made by driving the punch into copper. The punch itself is exactly like the final printed letter. The matrix is the reverse of this, and the matrix when placed in the type-casting machine (see Type Casting and Setting) is the source of the printing face of the finished movable type.

SIZES AND NAMES OF TYPE.

The sizes of type have been within recent years carefully systematized on what is known as the "point system." Formerly each size had its arbitrary name, as, for instance, nonpareil, minion, brevier, bourgeois, long primer, small pica, pica, English, great primer, and so on. Under the modern point system these sizes are known in order as 6-point, 7-point, 8-point, 9-point, 10-point, 11-point, 12-point, 14-point, 18-point, and so on. The "point" is an arbitrary standard, based on what is known as the standard pica, the latter being one-sixth of 996 thousandths of an inch. The pica size includes twelve points, and is modernly known as 12-point.

For the information of the reader there are here subjoined lines of type set in these various sizes, from 6-point to 12-point.

Six-point type.
Seven-point type.
Eight-point type.
Nine-point type.
Ten-point type.
Eleven-point type.
Twelve-point type.

There are in constant use several smaller sizes, as well as many larger sizes, than those above outlined.

The most used smaller sizes are 5-point and 5½-point, and there have also been cut 3-point and 4-point faces.

THE FONT, OR COMPOSING CASE.

An ordinary font of Roman type, by which is meant the sort of type in which this paragraph is printed, includes an alphabet of ''lower case,'' or small letters, an alphabet of capitals, one of small capitals, as well as italic capitals and small capitals. In addition to the characters involved in these five alphabets of twenty-six letters each, various characters are used, including figures, fractions, accented letters for foreign languages, diphthongs, or joined letters (as æ, œ), and various other characters having special uses. By reason of mechanical necessities, the following letters are cast together, in which shape they are known as logotypes: ff, fi, fl, ffl and ffi.

THE STANDARD LINE.

Some years ago a great reform in type making was instituted, when there came about the adoption of what is known as the ''standard line.'' Under this system the bottom of a letter ''a'' of 8-point in one style, or face, is at exactly the same line as the bottom of any other letter ''a'' of 8-point in another style, or face. An instance of the use of standard line follows:

THE STANDARD LINE.—Some years ago a great reform in type

WHAT TYPE IS MADE OF.

Type is cast from a metal made up of lead, antimony, and tin, with an occasional but very small proportion of copper. There has been no radical change in its composition for centuries. This combination has the quality of expanding slightly upon cooling, so as to fill the mold completely.

Each movable type has a face, a shoulder, a body, feet, a pin-mark, and a nick, or nicks, each having a definite purpose.

THE FASCINATING ART OF TYPESETTING.

The operation of setting type is fascinating to most people. A pair of wooden "cases" containing boxes for 152 characters is maintained on an inclined stand before the compositor, or type-setter. The "upper case" contains capitals, small capitals, fractions and other characters less frequently used. The "lower case," immediately facing the compositor, is divided arbitrarily into such compartments as will make most convenient to the hands of the compositors the letters most frequently used. Thus, for instance, the letter "e," which is used in proportion to "a" as seven to four, occupies the largest box, and is in the most accessible place.

Holding in his left hand an oblong metal frame called a "composing stick," the sides or jaws of which are arranged to the exact width of the line to be set, the compositor picks up one type at a time from its appropriate box, placing it in the stick, nick up, in such fashion as to cause the letters of a word to follow each other in due order. For each blank between words there is a bit of metal called a "space," and when the width of a line has been nearly reached, the spaces between the words which have made it up are readjusted so as to make the line moderately tight in the stick. This process is called "justification."

Placing in front of this line a thin strip of brass or steel, called the "composing rule," the compositor sets other lines in order, until the stick is full, when its contents are deftly lifted out and placed on an oblong brass frame called a "galley," in which, by simple means, it is later clamped, in order that a proof may be taken on a hand-press of some form.

THE CAREFUL PROOFREADER.

This proof is examined by the proofreader for errors that may have been made in the composition. Usually he has the manuscript, which is always in printing practice called ‘‘copy,’’ read to him. Upon the skill, fidelity, and broad education of the proofreader depend in a large measure the accuracy and good style of the printing in hand.

The proofreader uses various marks to indicate errors. He does not, as might be expected, form an ‘‘a’’ over an ‘‘o’’ which has been misplaced in the type setting, but instead draws a line across the offending ‘‘o’’ and indicates in the margin his desire for an ‘‘a’’ in that place.

THE LOCKING-UP PROCESS.

After the type has been finally corrected and the page or other printed form, often called a ‘‘job,’’ is ready for the actual printing, it is ‘‘locked-up’’ for press, or for the electrotype foundry. The process of ‘‘locking-up’’ consists in surrounding the type with various pieces of wooden or metal ‘‘furniture,’’ arranged inside a rectangular steel or iron frame, called a ‘‘chase,’’ in which, by the aid of wedges either of wood or metal, called ‘‘quoins,’’ the type may be rigidly secured and maintained with a perfectly plane surface. If the work is to be printed on a press, this chase next goes to the press. If, as is usually the case in book making, the printing is to be done from electrotype plates, the chase with its locked-up page or pages of type is sent to the electrotype foundry.

ELECTROTYPING.

Electrotyping is an important separate process, involving a separate trade. The process consists, first, in making from the locked-up type a mold in wax, which has been coated with pulverized plumbago, or black lead, this mold being made in a very heavy press called a molding press. Then follows an expert inspection, preparation and polishing of this mold, which is then placed in a bath of copper-sulphate, facing a copped ‘‘anode,’’ where, through the passage of a direct electric current of large volume and low voltage, there occurs the mysterious process of electrolysis, by which is formed on the face of the mold a shell of copper exactly duplicating the type which was used to make the mold.

When this shell has reached sufficient thickness, usually that of a piece of substantial writing paper, it is removed from the mold by having the latter melted away from it by the use of hot water. The shell is then stiffened for use in the printing press by being backed up with a soft grade of type metal, after which there occur various finishing processes that finally fit the plate for the printing press.

Electrotype plates may be used repeatedly, without keeping from other uses the type from which they were molded. Where books are printed from the product of type-casting-and-setting machines electrotyping is less resorted to.

The actual process of typographic printing refers particularly to that engine of modern civilization, the printing press, a consideration of which follows this article.

Presuming that the type pages or the electrotype plates have been successfully printed, on whatever form of press is used, there have resulted either sheets of printed pages arranged in what seems to be a mixed up fashion, or separate pieces of printed matter, complete as they come from the press.

"GATHERING" AND FOLDING THE PAGES.

The sheets, as of this book, for instance, include eight, sixteen, or thirty-two pages, and the arrangement when printed together has been such that when folded each page will follow in order.

In olden times these sheets were laboriously folded by hand, but the modern practice is almost universally to use folding machines.

When folded, the sheets are known as "signatures.'' If a book consists of 160 pages, and has been printed in 16-page sheets, or ''forms,'' it must be made up, obviously, of ten different 16-page sheets, now called signatures. The process of assembling these together is known as ''gathering.'' There then follows an inspection, called ''collating,'' to see that the gathering has been accurate; sewing by hand or machine, to hold the sections together; the making of a cover or ''case,'' and the bringing of the book and the cover together, all these processes being included under the trade known as book-binding.

Magazines are handled in substantially the same way as books, in printing, except for the use of specialized machines, which print, bind, and wrap for mailing at the same time any publication up to 96 pages which does not require a special cover. Newspapers, however, are produced differently, and in a most interesting fashion which can only here be briefly sketched.

STEREOTYPING FOR THE ROTARY PRESS.

The type-setting on a modern daily newspaper is largely done by one or the other of the type-making and setting machines. When the ''forms'' or pages are ready, they are stereotyped by means of a rapidly-made paper matrix, from which, with wonderful celerity, the necessary curved stereotype plates are produced. These are clamped to the cylinders of a great rotary machine, which produces, from a ''web'' or roll of paper, the newspaper as we see it, its pages assembled and folded, at a rate of speed that seems impossibly rapid.

The inks used in typographic printing are made usually upon a linseed oil base, with the use of pigments or colors, more or less finely ground in what is known as an ''ink-mill.'' Newspaper inks are soft and almost fluid, while the finer grades required to print the best illustrated work in black and in colors are finely ground and of a stiffer consistency.

EDUCATION IN THE ART OF PRINTING.

Thus is briefly sketched the art of typographic printing. There are manifold variations in which the young people who read these words will be interested, and of which they may readily learn by observation or by inquiry, and it is hoped eventually by much needed technical education. Curiously enough, the great art of printing, itself the underlying basis of human advance, has never been given attention in educational institutions until recently. Colleges have properly taught how to make a sick horse well, how to grow better turnips, fatter pigs, and to make bridges and engines and electrical machinery, but the very means by which and through which the teaching was done has been neglected. There is now in one great university a course in printing, in which men are taught the art, history and practices of this great art.

There are printing processes involving the use of photography through what is known as photogravure, gelatine printing, and the like. There are other processes which print by drawing out liquid ink which has been brushed into scratches or depressions, made in a copper or steel plate, as copper-plate, steel-plate, and the like. All these processes are important, but they are not used to anything like one per cent the extent of the typographic process; therefore they are here merely mentioned and not described.

THE EARLY, AWKWARD PRINTING PRESSES.

Without a machine that would actually do the forms of printing made possible by the invention of movable type, the latter would be of no use. The machine is therefore of equal importance with the type and the paper. All are essential.

The first presses were awkward affairs, giving the pressure that transferred the ink from the type—upon which it had been slowly dabbed by ''balls''—to the paper by means of screw pressure. That the old workers, who were truly artists, could do such superb printing as surviving examples show, with the crude appliances at their command, is a recurring marvel. They mixed their inks with brains.

TWO FORMS OF PRINTING MACHINES.

Without discussing the historical progress of printing machines, we may set down the two basic divisions into which they fall. The early presses, and those existing today as "platen" presses, did their work by pressing the paper between two parallel flat surfaces, on one of which the type "form" was secured.

The other form uses a cylinder, which presses the paper upon a flat surface or upon another cylinder.

In either case the ink is applied to the surface of type or engravings to be printed *from,* and the paper to be printed *upon* is brought into contact, by various means, lately of marvelous ingenuity.

THE OLD "PLATEN" PRESS.

The crude screw press of the fathers of printing was developed into a quite efficient machine which came to be known a hundred years ago as the "Washington Hand-press." It was upon an earlier but similar form of this press that Benjamin Franklin did the printing which made him famous. The various parts of this machine included essentially a "bed" of heavy construction—of stone at first, and later of iron—upon which the type "form" was secured, and which was moved back and forth upon "ways" upon which it slid; and a "platen," also of heavy construction, and hung above and parallel to the bed, so that when the latter was in place, the platen might be brought down upon it with such an even pressure as to do the printing. The paper to be printed was laid upon the "tympan," a canvas-covered frame hinged to the outer end of the bed, and to which there was attached the "frisket," to hold the paper in place accurately while it was being laid upon the form of type carried by the bed.

Inking was done, after the ''balls'' were superseded, by a roller, made of glue and molasses, upon which, by moving it rapidly back and forth over the ''ink plate,'' the ink had been previously distributed.

With two operators, and working vigorously, as many as three hundred impressions per hour could be accomplished on the best of these machines. Newspapers were printed thus; and the difference between modern and ancient methods may be most easily seen if one will visit Franklin's press, now preserved in the National Museum at Washington, and then see a modern ''perfecting'' newspaper press in the same city. Yet great deeds for America were done by reason of that dingy old machine upon which ''Poor Richard'' worked!

A form of platen press, in which the whole process was included in the machine, inking and all, was invented about the middle of the nineteenth century by Isaac Adams. There are yet in use some of these quaint machines, upon which certain work can even now be done to advantage.

In these days, the platen principle is used extensively for small machines, known as ''job presses,'' upon which cards, letterheads and the like are printed. There are two distinct forms of these useful presses, of which a far larger number is now in service than of any other printing machine. In one form, typified by what are known as ''Gordon'' presses, the bed and platen are caused to shut up together with the paper between them like the leaves of a book. The other form, usually known as the ''Universal'' press, rocks the platen forward to a position parallel to the bed—usually standing vertically—and then draws it to the impression while locked in this parallel relation.

Both forms use several small inking rollers which are caused to pass back and forth over an inking ''disc'' of a cylinder and then over the type or plates. Both, also, are ''fed'' with paper by hand; and many boys who read these words will probably enjoy ''feeding a press'' as much as did the writer of these words when he first began printing.

These smaller machines—the largest has a bed capacity of 17 x 22 inches—are speedy, efficient, and invaluable. Some forms are made of great strength, so that ''embossing,'' a process of pressing the paper between dies to raise the letters from the surface, can be accomplished.

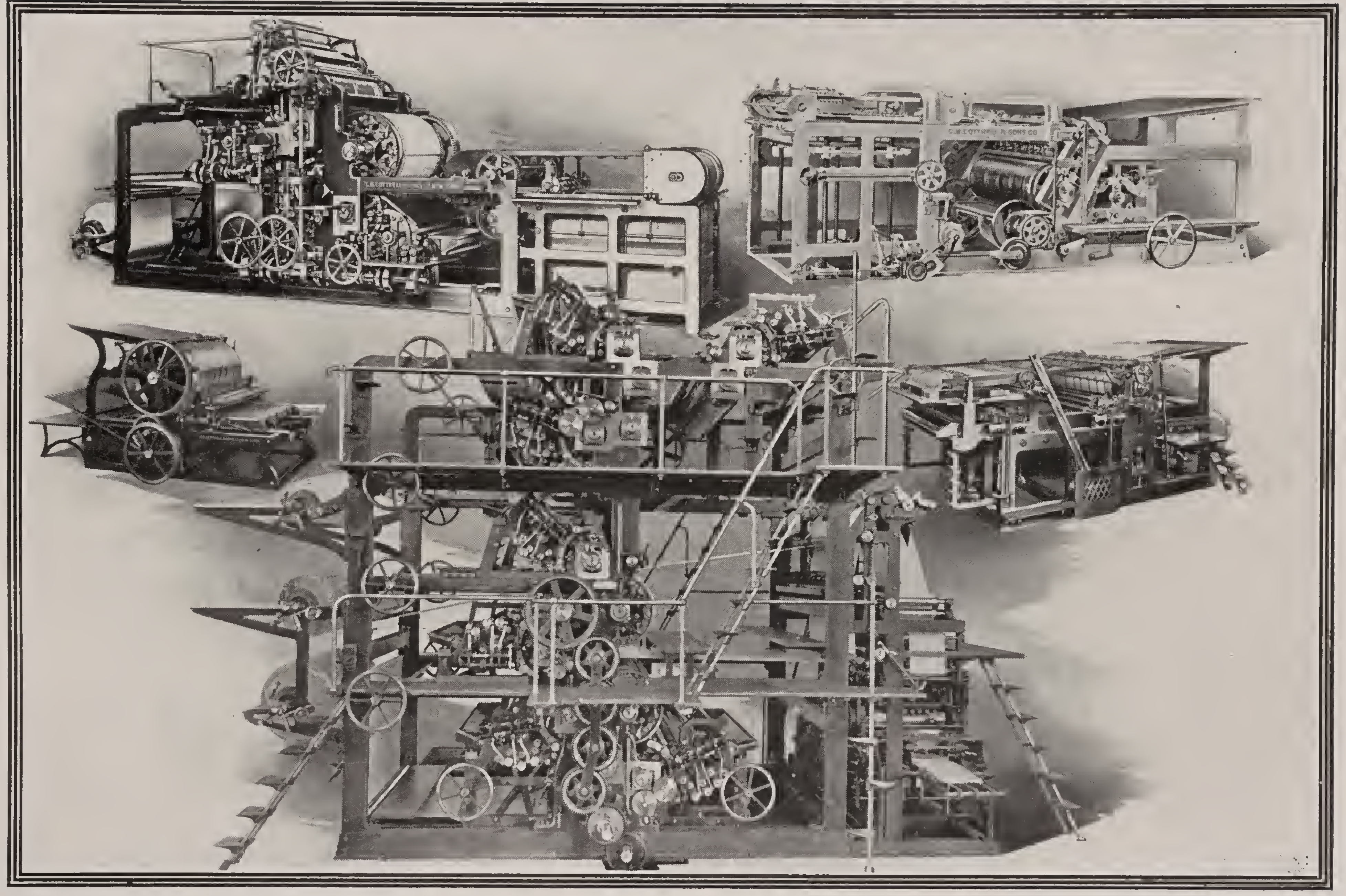
These machines are largely used for accurate ''color'' printing, involving the use of several successive impressions of different colors, one over the other.

THE WONDERFUL MODERN ROTARY PRESS.

It is to the invention in England by William Nicholson and Frederick Koenig of the ''cylinder'' press that the art of printing owes an advance only second in importance to the invention of movable type. The cylinder press at once trebled or quadrupled the speed, reduced the space required as well as the number of operatives, and generally made possible the modern newspaper, magazine, and book.

Cylinder printing presses are of two general classes. In the first—the original machine—there is a type bed carried back and forth under a cylinder upon which the paper is held by ''grippers'' as it comes in contact with the form to be printed from. The sheets of paper ''fed'' from a table, one at a time, by an operative, are automatically delivered upon a table when printed, by a ''fly'' or by some form of ''carrier.''

The ''rotary'' presses use two or more cylinders. One corresponds to the type bed of the older machines, and carries upon its surface electrotype or stereotype plates accurately curved to its radius. The ''impression'' cylinder carries the paper, either a single sheet



MODERN PRINTING PRESSES.—The machine in the center is a triple web rotary perfecting press, capable of printing, binding and wrapping ready for mailing 15,000 magazines of 96 pages each in one hour if no cover is required.

fed by hand or a separate feeding machine, or from a roll or ''web,'' so that it is pressed between the two and printed, delivery following and inking occurring by special mechanisms.

It is not difficult, upon the rotary principle, to use several pairs of cylinders, passing the sheet from one to the others, and thus printing it at one operation on both sides, or with several colors, or both.

By these large, complex, and efficient machines the modern multi-page, multicolor newspaper is made possible. As there is no mechanical loss, such as occurs in pushing and pulling the type-bed of the ordinary flat-bed machines back and forth, much higher speeds are attained.

The rotary principle has recently been applied with fair success to the higher grades of illustrated printing.

But, aside from newspaper and specialized magazine presswork upon rotary machines, by far the larger and all the better printing is now done upon the sheet-fed flatbed cylinder presses, and upon that perfected form in which the cylinder revolves twice to each impression, being ingeniously raised to clear the bed as it returns after its printing stroke. Such machines are called ''two-revolution'' presses. They are built to handle sheets of large size and with a very rigid impression, a certainty of having each impression strike in the same place—called ''register'' in technical phrase, and means for applying ink in a thin and finely divided film.

So strong and accurate are these machines that a sheet of paper may be fed through four or more times for the successive treatments required by modern color printing, with certainty that the press will bring the paper each time just where it ought to go, and this at a speed up to eighteen hundred per hour.

To many sheet-fed printing presses are now applied mechanical ''feeders,'' which supply the paper required with a speed and continuity impracticable to ‘‘hand feeding.’’

The earlier cylinder presses were ‘‘drum cylinders,’’ because they had large cylinders with some resemblance to a drum—making but one revolution to an impression. For a time, the finest printing was done on ‘‘stop’’ cylinder presses, so called because the cylinder was held at rest during the feeding of the sheet. These machines have been superseded by the perfected two-revolution, which runs at greater speed.

SPECIALIZED PRINTING PRESSES.

The scope of this article does not permit the discussion of many special printing presses. All that have been mentioned are for typographic printing, and there are specialized machines for doing particular things with speed and efficiency. The ‘‘offset’’ press is a hybrid between the lithographic and typographic processes. It is so called because the original impression—from either typographic or lithographic surfaces—is not upon paper, but upon a rubber blanket stretched around a cylinder, from which it is transferred to the paper carried upon another cylinder. It is possible by this means to print upon paper too rough to give good results under ordinary methods.

Probably the most interesting of the special presses, is the one used for printing the colored supplements of the Sunday newspapers. By skilfully dividing the ink fountains and combining colors and ‘‘overprinting’’ many shades are produced, one supplement showing as many as 36 different shades and colors. The manufacturers are now so efficient, that they can supply any demand of the printers.

There are plate presses, for the steel and copper plate processes; there are die presses, and machines for printing photogravures and other ‘‘process’’ results; but they do not fall within the scope of this article.

CHAPTER XXVI.

The Story of the Pen.

THE QUILL PEN AND THE SCHOOLMASTER.

WE get our word pen from the Latin *penna,* a feather, but the Latin pens were not generally made of feathers. The Romans used a ''stylus'' or pointed metal pen like an etching-needle, for they wrote on wax tablets, parchment, papyrus, and a number of other things, but not on paper. The quill pen did not come into fashion until writing-paper did. It was usually made of the outer wing quills of a goose, which are large enough to be cut into pen-shape, and the first penknives were used chiefly for making pens, which needed a small, sharp blade. In the schools of a hundred years ago a large part of the schoolmaster's work was making pens or mending them for the pupils.

WHEN THE SCHOOLMASTER GOT TIRED.

But it was so troublesome to keep making pens from time to time that many people began to use metal points fitted into a quill handle, and these were sometimes made even of ruby. Then a machine was invented, which is still used in Paris, for making quill pens, cutting them with a small circular saw; and the feathery part of the plume was used for making shuttle-cocks, artificial flowers and other things needing stiff feathers. But although people did not do so much writing then as now, or require nearly so many pens, there still seemed to be need for more pens than there were quills to go around, and the steel-workers of Birmingham, in England, began to devise metal pens which could be made cheaply by machinery.

FROM A SOFT TO A HARD PEN.

The first steel pen was a pretty close imitation of the quill pen, a small tube of steel with the point cut in nibs. William Gadbury, a maker of mechanical instruments, made one of the earliest steel pens from the mainspring of a watch, with two separate nibs. In 1820 Gillott made a steel pen with three slits instead of one, and the steel pen business began to grow. But these first pens were so stiff that they made a disagreeable scratching noise, and old-fashioned folk obstinately stuck to their quills. In such old-time storybooks as *The Wide, Wide World* telling of times long after steel pens were actually in use, we do not find them mentioned, and the children are still being taught to make quill pens.

Gillott not only perfected the steel pen but invented a great deal of the machinery to be used in making it; and today pen-making is one of the great industries of Birmingham.

HOW STEEL PENS ARE MADE.

The steel pen begins as part of a thin sheet of cast steel, sometimes made of Swedish iron, about four and a half feet by a foot and a half in size. This sheet is clipped into lengths one and three-quarters by four and one-half inches. These slips, in cast-metal boxes, are put in a furnace and kept white hot for about twelve hours—a process called annealing. When cooled, they are placed in revolving barrels to take off the scales and rough edges, then pickled in dilute sulphuric acid, and finally rolled until each little strip is 4½ feet long and only 1-160 of an inch thick, and so hot from the friction that it is difficult to handle.

Women and girls next cut out the pens by machine, and an expert worker can cut nearly thirty thousand a day. Then they are pierced, annealed again, and stamped with the maker's name. So far, the pen is a flat piece of metal.

The next step is to ''raise'' or curve the pen, after which it is again ''muffled'' in the furnace, and then suddenly plunged into a tank of oil and tempered, being afterward rolled in a quantity of sand to give it polish, the nib is ground on an emery wheel, slit, and colored. The finished pen is packed in a box with one hundred and forty-three others, one of a company of tiny scribblers that may go anywhere in the known world.

FROM STEEL TO GOLD.

Pens are also made of gold, silver, zinc and other metals, but the gold pen is the only one besides the steel pen which can be said to be popular. When gold pens were first made in Birmingham they cost a guinea each, for the slit in the pen had to be made with diamond dust, which was costly. Now they are slit with emery dust on a revolving copper cutter. The first successful American gold pens were made by Levi Brown, a watchmaker of Detroit. The great advantage of the gold pen is, of course, that it does not rust, and, if given proper care, will not wear out.

WHY THE TIP IS SLITTED.

Did it ever occur to you to wonder why the pen is slit at the tip? It is for the same reason that moldings are made in grooves on windows where rain runs down—because any liquid will run in a groove if there is one to run in; and the best pen, of course, is one which lets the ink run off it in a single line. When you press on the pen in writing it opens that groove a little—just enough for the ink to travel down instead of dropping off in blots. The heavier stroke of the pen opens the groove a little more, and lets the ink flow faster; and in the old-time writing school a scholar was not supposed to graduate until he could make an elaborate bird of heavy and light strokes and remarkable flourishes, all executed without lifting pen from paper.

THE STYLOGRAPHIC AND FOUNTAIN PEN.

About 1880 the stylographic pen began to be commonly used, and a little later the fountain pen came into fashion. The stylographic pen had a point like a pencil or like the Roman stylus, and had to be held in a different way from an ordinary pen, and having no flexible, split point, it would not shade.

The fountain pen is like any other pen, only that the handle is hollow, and filled with ink; and it is so arranged that the slight pressure used in writing lets out just enough ink to write with. The fountain pen was made possible partly by the invention of ebonite or hard rubber, for this makes a firm, light, cheap handle, and the cap fits closely, so that even if the ink should leak a little it will not spill into the pocket. Before this invention there was no way of being sure of having pen and ink at hand.

In the Middle Ages a man who was a scribe, or who was likely to have to do much writing, carried an ink-horn slung at his belt. This was sometimes a real horn and sometimes made of silver, but it had a tight lid, and when the scribe wanted to write he opened it, and dipped in his pen. But both pen and ink were costlier in those days than they are now.

CHAPTER XXVII.

The Labor-Saving Typewriter.

AN ART THAT STANDS MIDWAY.

MAKING characters by hand is very slow and tedious work. How many millions of weary miles human hands have traveled in writing it would be heartbreaking to estimate. Yet, one must exclaim in passing, what human labor ever so richly repaid all it cost!

From very early times, all sorts of devices have been employed to reduce the tedium and weariness of manual copying. Signatures were engraved on seals, and inscriptions made on wooden blocks. An art was needed and sought that should stand midway between writing and the printing process that involved too heavy and costly machinery for ordinary use. The invention of the typewriter was the logical outcome of the quest, as some one possessing rare prophetic instinct outlined in an article that appeared in the *Scientific American,* nearly half a century ago: ''The subject of typewriting is one of the interesting aspects of the near future. Its manifest feasibility and advantage indicate that the laborious and unsatisfactory performance of the pen must, sooner or later, become obsolete for general purposes. Legal copying, the writing of sermons and lectures, not to speak of letters and editorials, will undergo a revolution as remarkable as that effected in books by the invention of printing.''

FRANCE, ENGLAND AND AMERICA TAKE A HAND IN INVENTION.

Several nations divide the honors of early attempts at invention. The first machine that at all resembled a typewriter was constructed in 1714 by Henry Mill, an English engineer; the first patented in the United States appeared in 1829, and was called, rather grandiloquently, a ''typographer.'' The inventor was William Austin Burt. Then ingenuity shifted to France, where, in 1833, Xavier Progin, of Marseilles, evolved a contrivance, the first to use type-bars, that would actually write ''almost as rapidly as with an ordinary pen.'' That was some speed for those days, but America had not yet taken hold in real earnest and did not do so until many years later. Meanwhile, England tackled the problem again, and produced several machines; but, curiously enough, they were nearly all for the blind, and used embossed characters; this was true also of an early American typewriter patented in 1856, by A. E. Beach, which was a marked advance on others in covering a principle afterward developed in the modern machine—a circular basket of type-carrying levers, all printing at a common center. About this time, or a little earlier, Sir Charles Wheatstone, an eminent English scientist, was making experiments resulting in the construction of several machines that are now best known as curious exhibits in the South Kensington Museum.

A PRETTY RACE BETWEEN THE UNITED STATES AND ENGLAND.

The evolution of the typewriter had now settled down to an exciting and lively race between the two English-speaking nations facing each other across the Atlantic. But it was the United States that first got her second wind, in the breathing spell succeeding the Civil War. About 1866, John Pratt, of Alabama, but in London at the time—see how the race is still nip and tuck—devised a machine by which thoughts could be "printed twice as fast as one could write them, and with legibility, compactness, and neatness." It was an account of Pratt's invention that started another American, Charles L. Sholes, of Milwaukee, Wis., on a course of thinking and study which finally brought in the practical typewriter. Mr. Sholes had already perfected an invention for printing the number of pages in bound books, and a friend, Carlos Glidden, asked him one day, "If numbers, why not letters?" Even then the thought didn't take root, until they ran across the account of the Pratt idea. "That's it!" they cried, and sought out a third individual, Samuel Soulé, who became as enthusiastic as the others. The three then put their heads together, Glidden furnishing the money, Sholes inventing the spacing mechanism, and Soulé suggesting some features of the conveying type-bars. Finally, when more money was needed, James Densmore, of Meadville, Pa., came to the rescue, and Soulé and Glidden dropped out. From 1867 to 1873, machine after machine was built, put to severe tests, and discarded as defects were discovered, Sholes profiting by every mistake, and Densmore never losing faith in the final outcome. In 1874, the patents were sold to E. Remington and Son, of Ilion, N. Y., the gun manufacturers, who still further developed the device and exhibited it at the Centennial Exhibition, in Philadelphia, in 1876, where it excited great interest. So the race was won by America, and again, too, the pen was found to be mightier than the sword, for the warlike products of the Remingtons dropped behind the implements of peace, and the shot at Lexington that had been heard round the world found a counterpart in the merry click, click of the busy, useful, little instrument with which America has literally belted the earth.

DIFFERENT FORMS OF TYPEWRITERS.

There are three forms of typewriters—the type-bar, cylinder, and wheel machine. The first kind is in more general use. Its characteristic feature is the affixing of letters, hammer fashion, to the ends of narrow levers that are arranged about a common center. These levers are pivoted, and, when the free ends, terminating in a keyboard, are struck with the fingers, the hammer-like types press an inked ribbon against the paper and print their letters on it. By an automatic mechanism the frame holding the paper moves, after each impression, the proper space to the left.

In the cylinder machine, the letters and signs are on a cylinder or "sleeve," and, by the striking of the key, a lateral motion is produced which brings the type to the printing point. While the cylinder machines are not considered so rapid as those of the type-bar form, they have the advantage of allowing various types to be used, an absolutely perfect alignment, and more space for the wider letters. These advantages are possessed also by the wheel machines, where the types are placed on the periphery of a rotating wheel; but the speed of the latter is not as great as in the other kinds.

MAKING THE TYPEWRITER PERFECT.

Of course improvements followed thick and fast. At first, only capitals were employed; then a keyboard was used that had both capitals and small letters, and afterward a combination was devised—the ‘‘universal keyboard’’—with a shift-key to interchange letters and make use of punctuation marks and other characters. The writing was at first invisible, and the roller had to be raised whenever the operator wished to look over the work that had been done; but the writing is now ‘‘visible.’’ In many other ways efficiency and convenience were promoted, until the typewriter, in its perfected form, is a marvel of adaptation to its purpose.

Inventive genius then busied itself looking to ease of operation and eliminating noise. When man’s mind applies itself in earnest to problems like these, success is very sure to follow; it has done so in this case, at any rate. Typewriters are now driven by electricity or compressed air. They need an operator, to be sure, but the keytouch required is so slight that strain of nerve and muscle are greatly conserved. So delicate, indeed, is the action that a mere touch, a brush, releases the key; it is almost like the waving of a fairy’s wand. And the mechanical power does the rest.

In the compressed-air typewriter, the air in a ‘‘rotating vane’’ escapes through the keys by means of openings. When the finger caresses the key and the vane passes the closed tube, the flow of air through the vane is momentarily checked, and the character needed is pressed against the platen, and printed in the hundredth part of a second, so that the stoppage can hardly be perceived by the eye. As so much energy had hitherto been expended on the depression of the keys which can now be expended on manipulation of the brushing fingers, a decided gain in rapidity has been made.

So much nervous force has been lost, unconsciously but none the less surely, in the effort to resist the effect upon the system of the racket caused by typewriting, that a "noiseless" machine has been sought for, and is at last here. All previous attempts at reducing noise have been directed toward absorbing it after it was produced; but the problem has been solved, so logically that the strange thing is it was not thought of before, by simply *stopping all noise.* The principle is that of pressure instead of blows. No longer is the type thunderously hammered against the paper; it is merely pressed against it. There is high velocity of operation, but the velocity is checked just in time to make the impression, and no speed is lost. Ball-bearings are used everywhere to reduce friction, and the life of the machine, as well of the operator, is thereby lengthened. Imagine the gain in efficiency in a room where many typewriters are at work as quietly as though every person was using a pen—more noiselessly, even!

A BLESSING TO THE BLIND.

Typewriters are also constructed for musical work; for tabulating; and for writing in books. Their adaptation to the Braille, or other codes, for the use of the blind, is a beneficent device. Indeed, this instrument is a great boon to that unfortunate class, many of whom use the ordinary typewriter also, and with marvelous ease and accuracy.

The application of the typewriter mechanism to the special requirements of languages other than English, has been a problem that has occupied many inventive minds. These problems have all been solved, and at present every language, and many dialects have their special machine. One of the last to be perfected was an apparatus for the Arabic, which, having but a small number of letters in its alphabet, required nevertheless at least one hundred and eighty characters.

TYPEWRITING AS COMPARED WITH LONGHAND.

An interesting test made by the United States Department of Labor resulted as follows: "The unit required was the copying of a thousand words of statute law. This was accomplished by the typewriter in nineteen and five-tenths minutes; while a copyist with a pen required one hour and fourteen and eight-tenths minutes, or about four times as long."

The average speed of a good operator is from fifty to sixty words a minute. In contests, spurts have often been made in which the rate was far over a hundred words a minute.

AMERICA'S CONTRIBUTION TO THE SPREAD OF KNOWLEDGE.

Over two hundred thousand typewriters are now being manufactured annually in the United States, half of which are sent to other countries. Thus this little machine is playing a large part in the advancement of universal knowledge and the march of civilization.

CHAPTER XXVIII.

The Microscope.

A DOORWAY TO A NEW WORLD.

THE microscope has been called the doorway to a world of wonders. It is also said that no one possessing this little instrument need ever be lonesome, for it always introduces the student to something interesting, curious, surprising, and mysterious. Although one sees a great deal with his eyes, the microscope proves how little is really seen, and how an entire new world, whose existence has been unsuspected, lies outside the field of vision.

THE DISCOVERY OF THE MICROSCOPE.

The microscope was discovered just about the same time as the telescope. The word is derived from the Greek, and means "to see small." It was not regarded very seriously, since no one knew how to apply it. Just as the phonograph was first used in a talking doll, and was lightly esteemed, but afterward became one of the greatest educational adjuncts, so the microscope made for itself a definite place in scientific investigation.

The discoverers were Hans and Zacharias Janssen of Middleburg, Holland, and the time was about the year 1590; they were spectacle-makers, and they found that, by placing two convex lenses in such relative positions, that one would magnify an enlarged image formed by the other, they could see many objects hitherto invisible. The great Galileo is also credited with the marvelous discovery.

TWO KINDS OF MICROSCOPES.

There are two kinds of microscopes, the simple and compound. The compound binocular microscope is so-called because it has two tubes, one for each eye, and has also two sets of lenses. A lens is a glass that is cut thick in the middle and thin around the edges. The tiny object to be examined through the magnifying glass, is first reflected in the object glass, and then the reflection is magnified in the eye glass. The size may be increased to the incredible number of five thousand diameters.

HOW THE MICROSCOPE SAVED INDUSTRIES AND LIVES.

Not long ago two important industries of France were threatened with annihilation. One was the wine product, since the vineyards were being destroyed by some parasite; the other was silkworm cultivation. Louis Pasteur, by the aid of the microscope, discovered the disease which had meant destruction to these industries, and thereby ruin was averted. Through the agency of the microscope he also made many other remarkable studies of bacteria and germs, which have been of much benefit to mankind.

THE AMATEUR MICROSCOPE IN THE HOME.

The great high-power microscope that has accomplished so much in adding to scientific knowledge and conquering disease, is matched in less degree by smaller instruments. A microscope of even low diameter, that can be purchased for only a few dollars, and be used at home, is of endless interest and pleasure. Place under it such a tiny and fragile object as a fly's proboscis, for instance, or a butterfly's "feathers"—how many know that a butterfly has feathers?—and the wonder aroused by the beautiful sight will lead to further delightful research. One will find that the infinitesimal world opened by the microscope is as inexhaustible as the boundless realms of space revealed by its antipodal companion, the telescope.

CHAPTER XXIX.

The Telescope.

THE LENS AND THE WEATHERVANE.

THE telescope is an optical instrument with which to observe distant objects on the earth and in the sky. The word is derived from two Greek words meaning "to see afar." The instrument was invented in Holland in the year 1609 by three different men, Lippershey, Janssen and Metiers, although Roger Bacon wrote about the telescope in 1250. Galileo has the credit of the invention, however, for as soon as he heard what the Hollanders had done, he at once caught the idea, and invented a telescope himself that was superior in every respect to Lippershey's instrument. He was in Venice at the time, and he carried the model of his invention to the Senate, and was duly honored. As Galileo was an astronomer, he at once made further valuable discoveries—among others the spots on the sun, the lunar mountains, the moons of Jupiter, and the phases of Venus. Lippershey was a spectacle maker, and it was while he was holding two lenses one day in a certain position that he caught the reflection of the weathervane on a distant church-spire, and observed to his amazement that it was brought surprisingly near to him; then the other spectacle-makers heard of it, and they at once proved the same idea. The time was then ripe for the discovery of the telescope, and all the discoverers became famous.

THE FIRST REFLECTING TELESCOPE.

It would take too much space to describe how a telescope is made, for that includes the laws of light and lenses, both of which are exceedingly scientific. They are sufficiently interesting, however, to invite individual research. Sir Isaac Newton improved upon the telescope about a century after Galileo's time, adding a mirror to it; and from his idea great improvements have been made. The first reflecting telescope was about six inches long, and contained a mirror that measured one inch in diameter. The instrument is now in the possession of the Royal Society of London, and bears this inscription: "The First Reflecting Telescope, Invented by Sir Isaac Newton, and Made with His Own Hands."

GREAT TELESCOPES OF THE WORLD.

After Newton's invention the reflecting telescope came into extensive use. Its chief development was due to Herschel, the astronomer, who, in 1775, constructed a famous instrument having a forty-foot reflector, with which he made important discoveries. Lord Rosse's great telescope is the next notable one. It was set up on his own estate in Ireland in 1847. He was an amateur, and built the instrument himself, devoting seventeen years to its construction. The tube was no less than fifty-eight feet long, and seven feet in diameter; a man holding a raised umbrella could easily walk through it. There was a system of staircases, one leading to another, all at various ingenious angles, which one must ascend in order to obtain access to the eye-piece at the lower end of the tube. The story of it is most interesting, and is well worth reading.

One great telescope after another has been built since, in different parts of the world, to explore the fascinating wonders of the heavens. There are great instruments in Paris, in Greenwich, in Heidelberg, in Potsdam, in Pulkowa and many other European cities; these are only a few of the many in the world, among the first of which are those in the United States.

FAMOUS TELESCOPES IN THE UNITED STATES.

There is a splendid one at Harvard, and one in Washington, but the greatest are at the Lick Observatory on Mount Hamilton, Cal., the Carnegie at Mount Wilson, Cal., and the Yerkes at the Observatory of the Chicago University established at Williams Bay, Wisconsin, eighty miles from Chicago. All three are now in the zenith of their usefulness. The Lick Observatory is situated nearly five thousand feet above the sea level, and in a remote and lonely spot. Indeed, loneliness and height are characteristic of observatory location; so that it is something of a sacrifice to be an astronomer. No star can appear and not be charted, and wonderful photographs of the heavens are now made. Electric motors move the great instruments by the pressing of buttons, and an intricate mechanism controls the whole.

The modern telescopes are not very much like those of Galileo and Newton, but, starting from these primitive contrivances, our great instruments are the perfected result of centuries of inventive, scientific thought.

CHAPTER XXX.

Photography.

A BLACK BOX WITH A NEEDLE HOLE IN IT.

PICTURES called photographs depend on two principles. The first principle was discovered a long while ago. It was found that, if a very fine hole be made with a cambric needle in one side of a cubical, closed box, black on the inside, and a piece of white paper be placed in the box opposite to the needle hole, a picture of the view in front of the hole is formed on the paper. This picture can be seen if desired, by covering all the box, except the needle hole, with a piece of dark cloth, and lifting the top of the box. It is an accurate reproduction of the outside scene except that the objects in it are inverted—that is, if the picture is that of a tree, the top of the tree will be downwards, and the roots or base of the tree upwards. Such a box was made by an Italian, Giambattista della Porta, way back in 1569, and he called it the "camera obscura."

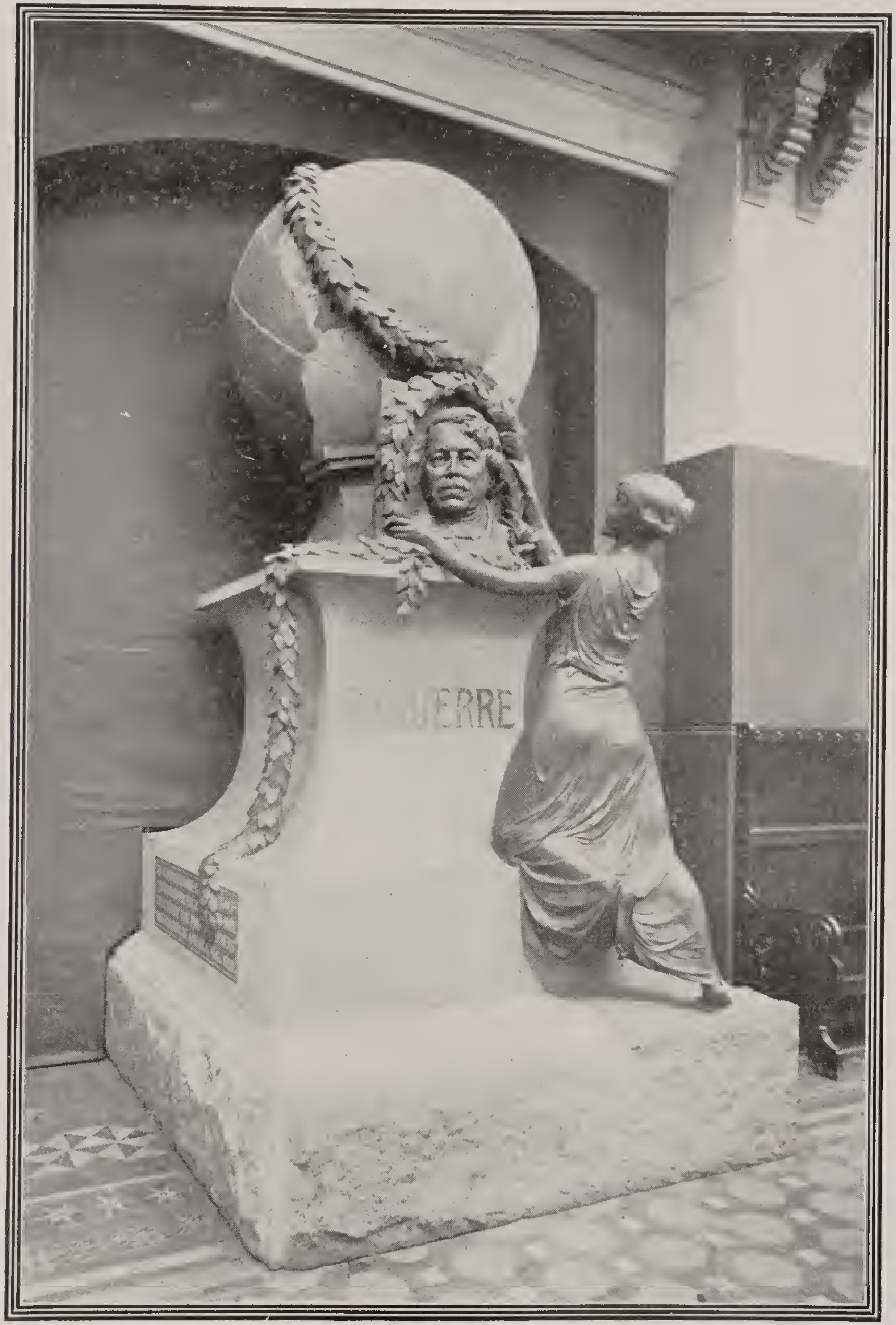
But if one needle hole would admit the light and form a picture, why would not two holes admit more light and produce a better picture? Happy thought, until it was tried! Then it was found that two holes made two pictures, and they overlapped each other in such a way that the outlines of both were blurred. So it was—another happy thought, and this worked!—that Porta put a lens in front of the aperture—a spectacle glass, at first. It gathered up, or magnified, a greater number of rays of light and focused them. Here was a distinct picture with clear outlines, only waiting perfection by later investigators. This is the basic principle from which the beautiful camera of today, with its many convenient attachments and improvements, has been developed.

CHEMISTRY COMES TO THE AID OF THE CAMERA.

The other fact that makes it possible for us to take photographs has to do with chemistry.

It had been known, of course, ever since man began to observe, that light visibly affects matter; but it was not until the latter half of the eighteenth century that men began to look for the cause, and to seek for practical results. Then Scheele, a Swedish chemist, began to experiment with silver chloride, and it proved to be the key that, in the hands of others, was to unlock some of Nature's most delightful secrets. This is a white material when kept in the dark, but one which changes color on being exposed to daylight—first gray, then purplish, and finally black, depending on the time of exposure. Scheele was followed by other experimenters, no one of whom appears to have thought about using it as a means of picture-making, until, in 1791, ''Tom Wedgewood, the first Photographer,'' hit upon the happy application. It was Nicephore Niepce however, who, in 1827, made the first camera image; and Daguerre and a man named Talbot, simultaneously, seem to have overcome final difficulties and made practical photography possible. This was in 1839.

The process of using the magical silver chloride is extremely simple. It need only be spread in a thin



Monument in the National Museum at Washington, D. C., in honor of Daguerre, the Discoverer of the Art of Photography.

layer on a white surface, and then, placing the "plate" in a camera, let the light fall upon it through an aperture and a lens. Wherever the light strikes the surface we get a darkening, and the amount of darkening will be dependent upon, and precisely proportioned to, the amount of sunlight falling on each point of the surface. But, curiously enough, the picture is not only upside down, as has been noted, but the colors are reversed. All the bright parts in nature are dark in the picture, and dark objects produce little or no blackening on the paper; so that the surface of the silver chloride paper appears changed exactly according to the way in which the light has fallen upon and affected it.

OTHER STEPS TOWARD THE FINISHED PICTURE.

These are the two main facts upon which the production of a modern photograph depends; but many other processes are necessary to complete the beautiful, finished photograph of today. Indeed, the art has been so very greatly improved in modern times that almost any one can now take a picture that is quite good in its appearance, and needs no great skill on the part of the person who is making it.

THE DARK ROOM AND THE NEGATIVE.

When the sensitized plate is drawn from the camera after the picture has been taken, it must be carried at once, covered, to a "dark room" for "fixing" or "setting," the picture. The room is called dark, but a dim red light is burning there to enable the photographer to see, for red light does not act upon the plate as a white light would do. We have Sir John Herschel to thank for the discovery, in the wonderful year 1839, which meant so much to the picture-making art, that hyposulphite of soda dissolved out all the silver not affected by light, thereby fixing the image. So, in the dark room, the plate is given a short bath in a solution of sodium hyposulphite and comes out, after being washed and dried, a permanent picture in white upon a black ground. Owing to the fact that it is a reversed picture, as far as light and shade are concerned, it is called a negative, the true picture afterward printed from it being called a positive.

GUN COTTON AND ITS AID IN PICTURE-MAKING.

In spite of the care used in selecting the paper for making pictures, both negative and positive, it was found that no pictures were perfectly sharp and clear-cut—that is, sharp objects in the view did not produce correspondingly sharp lines or impressions on the finished positives finally made. The difficulty was that no paper could be produced that did not have a texture or grain to it; and this was a great drawback. Nevertheless, the pictures were very pretty, indeed quite beautiful, and they were wonderful when it is remembered that no other method of producing the picture as accurately and as rapidly was at first known. It was not until the advent of another discovery that it was possible to make any pictures approaching in perfection those of the present day.

About the middle of the last century, gun cotton was discovered, and it was found that this substance, when made in a certain way, was soluble in a mixture of alcohol and ether. If this solution of gun cotton was then floated upon a glass plate, and the alcohol and ether were allowed to evaporate, there was produced upon the surface of the glass plate, a structureless film, absolutely free from texture or grain, and admirably suited to carry the silver chloride or other compounds needed to make photographs. Another discovery was then made, viz., that a solution of gun cotton could be mixed with an alcohol solution of certain salts, such as cadium and potassium iodides and bromides, and that the solution could be combined with the gun cotton solution in alcohol and ether. It was also found that this combined solution, when spread upon a glass plate, made a transparent film which, when dipped into a water solution of silver nitrate, produced in the film iodide and bromide of silver in a marvelously minute form. Here then was obtained a sensitive silver surface, or film, admirably suited to grainless negatives. The fact that these negatives were produced on glass made them easy to handle. If now, such a structureless film containing the iodide and bromide of silver, was placed in a camera, and a picture impressed upon it by light through a lens in the manner before described, we should obtain an impression upon such a plate that, when developed with certain chemicals, would create a negative image of the same character as described in our first experiment with the silver chloride; but it will be noted that the effect of light upon the iodide and bromide of silver, does not at once produce the blackening which we noted upon the silver chloride image. An intensification of the effects of the light was procured by means of chemicals called developers. There are several of these chemicals, the most commonly used being copperas, which is ferrous sulphate; and the other is pyrogallol, an organic body derived from nut galls. There are a variety of other substances upon the market now used by amateur photographers for making these developed images.

DRY-PLATE PHOTOGRAPHY.

Such was the state of the art until about the year 1878, when Doctor Maddox suggested, used, and perfected the gelatine bromide plate. The use of collodion with alcohol and ether had always been somewhat dangerous owing to the inflammability of the materials. Furthermore, it required a great deal of skill to coat evenly a glass plate with such a mixture, because of the rapidity with which the collodion, alcohol, and ether evaporated. It was only in later years that a perfectly uniform film upon the glass plate could be obtained, beginners getting spots and streaks and most mysterious markings upon the surface of the negatives. By taking a mixture of gelatine, such as is used for making jellies in the kitchen, and putting into it, while warm, nitrate of silver, and then mixing into that the necessary bromide and iodide—often bromide and iodide of potassium—it was found that one could produce silver bromide and iodide in an exceedingly fine state of division, these being formed in absolute contact with the gelatine. By allowing the warm mixture to cool, it set, just like blanc-mange or jelly. It could then be washed, in a dark room, to get rid of the salts used to form the silver bromide and iodide. After being washed, it was ready to be melted and spread upon glass plates.

The film of gelatine thus formed made the instantaneous picture possible, a feat never before approached in photography. Another great advantage is that the plates may be kept for an almost indefinite time, and can be used in places and under conditions not to be thought of with the old collodion negatives.

This is modern dry-plate photography, under whose happy auspices it is necessary only to go to a photographic store, buy the plates, put them in a camera, snap the shutter and, lo, a picture! It is then possible for any one, with a dark room and a few simple dishes and chemicals, to develop the pictures at home.

The most recent development in the photographic art, has to do with ''color-photography''—the reproduction of the natural colors of the object photographed. Certain results along this line have been accomplished, but as yet the processes are too intricate to be readily understood, are very expensive, and not possible for commercial use; but the day is not far distant when an amateur will be able to ''press the button,'' and capture the colors, as well as the shapes and shades of his subject.

CHAPTER XXXI.

The Thermometer.

WHAT THE THERMOMETER IS NOT.

THE thermometer is an arbitrary scale for registering temperature, not, as was formerly supposed, a measure of heat. For instance, you may place two thermometers, one in a barrel of water, the other in a glass of the same water. The barrel of water will contain *more* heat than the glass, because there is more capacity for holding heat; but the *degree* of heat in each utensil is the same, and the thermometers will register alike.

WHAT THE THERMOMETER IS.

The gas thermometers—called ''air,'' ''hydrogen,'' and ''nitrogen'' thermometers—were probably the first to be constructed, and are still the standard in scientific work requiring very great accuracy. The mercury thermometer quickly followed and, with the occasional substitution of alcohol for mercury, is generally used for all practical purposes. Alcohol, usually colored red so as to be more easily seen, is used when temperatures are to be registered below minus forty degrees F., as mercury freezes at that point; but it cannot be used where the temperature to be registered is likely to go over two hundred and twelve F., for, at that point, the vapor pressure would burst the bulb. Alcohol also allows wider spaces between the degree-marks, and hence, where only a short range of stem is required, the scale may be subdivided, with distinctness, into half and even quarter degrees. The principle of the thermometer is the expansion of liquid in a vacuum tube when heat is applied to the bulb or stem, and its contraction as heat diminishes or cold approaches.

HOW THERMOMETERS ARE MADE.

The manufacture of thermometers is a simple process. The mercury or alcohol is placed in a tube, and, when the bulb is heated to the boiling point, the tip of the tube is closed with a blowpipe, which melts the end. The liquid settles, when cool, at the point, indicated by an annexed scale, corresponding to the temperature of the surrounding atmosphere; and it then rises or falls in the vacuum according to changes of temperature in the weather or in any substances in which the completed instrument may be immersed. There are thus only four parts to the thermometer; the liquid; the spherical bulb which contains it; the tube which makes expansion and contraction evident; and the scale from which the changes are read.

THE THREE STANDARD GRADES OF THERMOMETERS.

The "Centigrade," or "hundred-degree" system, is used in France, popularly, and in scientific work throughout the world. The interval between two fixed points is divided into one hundred equal parts, from zero, the freezing point, to one hundred degrees, the boiling point.

In the "Reaumur," used in Germany for household purposes, the interval between freezing and boiling is divided into eighty equal parts, or degrees.

In the United States and England, the Fahrenheit thermometer is in general use. In these countries, the interval is divided into one hundred and eighty spaces; but the freezing point is fixed at thirty-two degrees, and the boiling point at two hundred and twelve degrees. The reason for this is not clear; but there can be no doubt that Fahrenheit's zero point represented the greatest cold that was known in his day—the temperature obtained by mixing salt and ice. He probably sought to avoid the use of minus figures; but, in these days, cold several hundred degrees below zero can be produced, and we now adhere to the 32-freezing-point system simply from custom, though its original significance is lost.

DIFFERENT KINDS OF THERMOMETERS.

There are thermometers of various kinds, each adapted to its particular use. There is the clinical thermometer, which the doctor sticks in your mouth when you already feel sick enough, and which the Irishman said he had taken into his mouth every hour, according to orders, but didn't feel any better, as he hadn't succeeded in swallowing it yet. Then there are the deep-sea thermometer; the dew-point thermometer, which determines at what point dew will be deposited from the air; the wet-bulb thermometer, for ascertaining the amount of humidity in the air; the radiation thermometer that indicates the intensity of solar or terrestrial radiation; and the upsetting thermometer, that is thrown from its equilibrium by clockwork and records the temperature that prevails at any particular hour.

LOOKING AT THE THERMOMETER.

In very hot or very cold weather, it is just as well not to look at the thermometer too often, as, by suggestion, it only crystallizes your discomfort and makes you feel hotter or colder than its figures indicate.

CHAPTER XXXII.

The Barometer.

MEASURING THE WEIGHT OF THE AIR.

THE barometer is an instrument for determining the weight or pressure of the atmosphere or air overhead. It was discovered by a man named Torricelli. He was experimenting with mercury, the liquid metal. He found that, if he took a tube less than thirty inches long and open at one end, filled it with mercury, and then, having closed the open end of the tube with his thumb, inverted the mouth of the tube in a vessel of mercury, the mercury remained in the tube. If, on the other hand, he took a tube of the same kind, closed at one end, but thirty-six inches long, he noticed that, on filling it with mercury, and closing it and inverting it as before, the mercury stood at a level of about thirty inches above the surface of the liquid metal; and above that level there was a vacuum. Torricelli argued that the reason the mercury stands at thirty inches in the barometer tube is because the pressure of the air upon the surface of the mercury in the vessel pushes it up into the tube towards the vacuum until the column of mercury balances the outside air.

HOW THE BAROMETER PLAYS SEE-SAW WITH THE AIR.

The mercury, however, does not remain at the thirty-inch point, but varies in different localities; and even in any one barometer, at any given point, the column moves up and down in exact correspondence with changes in atmospheric conditions. The important service performed by the barometer, then, is in registering and foretelling changes in the weather. Air is lighter in weight before a storm, and, consequently, does not exert so great a pressure on the column of mercury; a ''falling barometer,'' therefore, gives warning that it is a good time to seek shelter. ''High barometric condition,'' on the other hand, indicate fair weather; and this usually means lighter hearts as the air grows heavier. The height at which the mercury stands also varies according to its distance above the sea level—barometers on mountains, for instance, having a mean average level lower than barometers on a plain. This principle is used in determining altitudes, but in aviation, the aneroid barometer is employed because of its compactness and convenience.

A TALL BAROMETER.

It is not necessary to use mercury in the manufacture of barometers, though that metal is the most practicable. Glycerine and even water have been used, but these and other substances require a tube thirty feet long, which is, to say the least, somewhat inconvenient for ordinary use.

ANEROID BAROMETERS.

Aneroid barometers are not so accurate as the mercurial instruments, but have the advantage of being portable, and so are more serviceable in recording heights. There are various forms of the aneroid barometer, but the most common is a round metal box, exhausted of air, with a lid of metal so thin and elastic as to record every change in atmospheric pressure.

CHAPTER XXXIII.

Medical Discoveries and Inventions.

INVENTIONS THAT AID THE SENSES.

IT has puzzled many to account for the sudden and remarkable advance in science during the past quarter of a century. Truly it may be said that more progress has been made during that time, towards an understanding of the world in which we live, the universe which surrounds us, than in all the centuries which have preceded it! The progress has not been slow, but sudden. This is not due to the fact that men are essentially wiser and have better minds than formerly; for it is generally acknowledged that Aristotle, who lived in Greece more than three hundred years before Christ, possessed the finest, all-embracing mind the world has ever known. Although the mind of men has made but little progress, yet we know much more about the universe than did the Ancients. Why is this?

The answer to the question is found in this—that nearly all recent progress has been made possible by means of delicate instruments which enable us to see more clearly and deeply into the structure of the universe than we otherwise could; to measure vibrations; to get in touch with far more of the world of matter and of force than is possible with our unaided senses. For the senses can perceive only a very limited range of facts, and all that lies outside of their small circumference must, without additional appliances ever remain unknown to us. So, although this wonderful inner world always existed, for the ancients, as well as for us, they could never get in touch with it, weigh it, see it, and measure it, because they had not the delicate instruments with which to do so. It is only because we have these that we can penetrate far more deeply into nature than they could. Thus, progress in science and in our understanding of nature and ourselves, depends almost entirely upon improved devices and instruments; and this is as true in medical science as in any other.

Let us see, then what these improvements are. Discoveries about the body in which we live are always interesting; and an account of some of these instrumental methods of diagnosis, the recognition of a disease from its symptoms will prove of very great interest.

AN ELECTRIC LIGHT INSIDE THE BODY.

Since the body is not transparent, the question of finding out what goes on inside it remained for many years an unsolved problem. There seemed no direct way of seeing into the body; but now this can be done! It has been rendered possible by the discovery and development of electricity—which shows how one science helps another, and one discovery renders another possible. The soft parts of the body, its walls, are more or less transparent, as you can ascertain by holding up your hand, with the fingers closed, against a very bright light. Seeing this, it occurred to various doctors that if it were possible to introduce a light into the interior of the body, it might illuminate it, and through the walls, thus rendered somewhat transparent, these internal workings could be observed.

But here came the difficulty; how could this illumination be introduced? Obviously, it was impossible to lower a lighted candle or oil lamp into the human stomach, and yet how otherwise obtain the necessary light? Then the introduction of electric light placed in the hands of physicians one of the most valuable aids in diagnosing disease.

Thus, a small but powerful electric light is introduced into the stomach. This does not interfere with its functions, and the lamp can be withdrawn at the conclusion of the examination. When the light is turned on, it illumines the inside of the stomach, and renders more or less transparent the body covering these parts, enabling the physician to watch the processes of digestion and alimentation. In this way he is enabled, as never before, to make various tests of the greatest value.

In the same way, other parts of the body may be examined by means of small electric lights, introduced into the various openings or apertures. A small instrument, called the auroscope, is employed in various diseases of the ear; this enables the attending physician to expand the walls of the ear artifically, and then, by means of a small electric lamp, placed within the ear, to study it in detail. A somewhat similar contrivance is employed in examining the nose, the lower bowel, the bladder (including even the small tubes leading to the kidneys), and the lungs themselves, the latter by means of the "bronchoscope."

HOW ONE MAN LOOKED INTO ANOTHER MAN.

But there are other ways of finding out what goes on in the stomach and the digestive tract during the processes of digestion. Nearly a century ago, Dr. Beaumont wrote a monograph upon his observation on the human stomach during digestion. This book has been, until recent years, the chief source of information on these subjects, for medical men. Dr. Beaumont owed his important observations largely to an accident. A man came to him for treatment with a gaping wound in his side—the result of an accident—and, by carefully opening the lips or edges of this wound, it was possible to observe the stomach in operation. Oddly enough, the patient did not suffer in any direct way, so that studies of his condition were continued for a number of years uninterruptedly. The effects of various foods, changes in digestion caused by the emotions, etc., were all observed and noted by Dr. Beaumont.

A BUTTON LIKE AN OYSTER SHELL.

Progress in this direction has, however, been slow. One of the earliest methods consisted in washing out the stomach of the patient at regular intervals, and analyzing the contents. Thus, food may be taken at noon; by half-past twelve a certain amount of change has taken place in the food eaten, and when this is examined, the changes may be noted. If such examinations be made every few minutes throughout the whole period of digestion, on hundreds of different patients, it is obvious that much valuable information can be obtained as to the chemical changes which take place. The effects of different kinds of food can also be seen; how long they take to digest, etc.

An extension of this method has recently been devised, by means of which it is possible to examine the contents of the duodenum—the small, secondary stomach, into which the food goes when it leaves the stomach proper. After the food has been churned up sufficiently in the stomach, it is passed along to one end where there is a small valve, or opening, through which food is pushed by certain complicated muscular movements of the walls of the stomach. The little valve opens and admits the food, which thereupon passes into the duodenum. It is a wonderful provision of nature that this little door will not open until food is quite ready to pass through it; yet, if a button or other solid object be swallowed, the door will let it through, and pass it along to the bowels with the rest of the food, as if it somehow knew that it could never be digested and liquified in the regular way.

Now in the duodenum many important chemical and other changes take place; but, until lately, it has never been known exactly what these were. By means of a newly invented instrument, however, they can now be examined. The patient is allowed to swallow a small, metal, button-like object attached to a fine tube. The other end of this tube projects from the mouth, and is affixed to a small pump. In the course of digestion, as before explained, the little valve at the end of the stomach, finding that the small button cannot be liquified and digested in the usual manner, passes it along, and in it pops, into the duodenum. Once here, the button can be made to open, like an oyster shell, and the contents of this small sack or bag be drawn upwards and out of the body by means of a very delicate suction pump. The button and tube may then be withdrawn, and the contents of this organ examined at leisure. The importance of this method of diagnosis will be apparent when it is stated that the chyme in the duodenum has never before been obtainable in any direct manner, although many of the most important steps in digestion take place in that part of the digestive tube. It is apparent that medicine also may, by this means, be introduced directly into the duodenum, by way of the stomach.

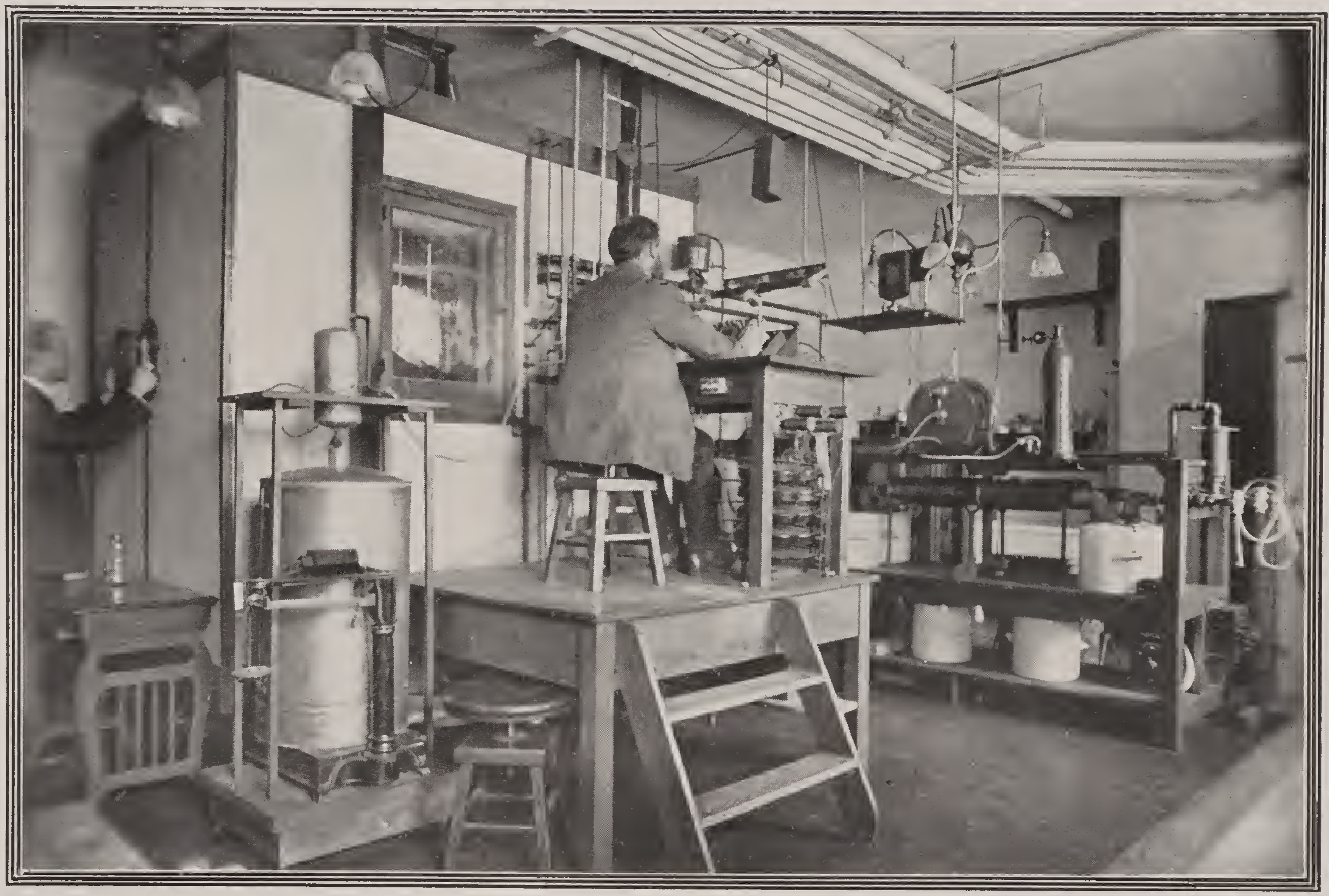
HOW THE LUNGS AND HEART PUT THEMSELVES ON RECORD.

In diseases of the lungs, however, none of the methods so far mentioned would be of any avail, for in many of the minor ailments nothing would be discoverable by such exploration, even if made. Recourse is, therefore, had to other methods of diagnosis. One of the most useful instruments so far invented is the stethoscope, which enables the physician to hear, with greater distinctness, every sound within the lungs. A small, cup-like object is placed against the patient's chest. This is attached to two tubes, terminating in ear-pieces, which the physician places in his ears. The result is that every sound within the chest is magnified, and rendered clearer, so that, if scraping sounds are emitted by the lungs when they expand in breathing, or if only part of the lungs is acting, this can be instantly detected.

Then, there are instruments for measuring the rate of respiration, of the pulse beat, etc. An instrument is attached to the body by means of straps, and the variations are recorded on a revolving drum of smoked paper, turned by clockwork, so as to obtain absolute accuracy. A fine needle-point marks or scratches on this smoked paper, and a permanent record is thus obtained of the variations which the instrument records.

MEASURING THE TIRED FEELING.

A somewhat similar instrument has been invented for measuring the degree of fatigue in a muscle. When a muscle does work, certain poisons form within it which prevent it from continuing to work beyond a certain period. When these ''fatigue poisons'' have reached such a degree of accumulation, the muscle must rest; if it does not do so, then very serious results follow, that may take a long time to cure; but the fatigue comes on very gradually, and the rate of its progress can be measured. The instrument of meas-



A RESPIRATION CALORIMETER.—The apparatus in use in a laboratory of the Agricultural Department at Washington.

urement is attached to the first finger. By raising the finger a number of times, a small weight is raised, which, after a while, tires the finger. The movements then become slower and more irregular; and all this is shown on the smoked paper, as before explained. In this way, the ''fatigue curves'' can be traced.

A THREE-FOLD DIAGNOSIS.

The temperature of the body is gauged by means of a small thermometer, called the ''clinical thermometer.'' It is like the glass part of any other thermometer, without the wooden support; and the degrees are cut on the glass itself, instead of on the wood. This thermometer is very delicate, however, and only measures temperatures between 95° and 110° F. The normal temperature of the body is about 98.6° F., and if it is much above this, we know that fever is present; if much below, lowering of natural heat and vitality is indicated. So, when the thermometer is inserted beneath the tongue, or under the arm, or elsewhere, as the doctor sees fit, the mercury at once indicates the state of health as far as temperature can register it. It is usually a very important test; and, together with the pulse rate and the condition of the tongue, helps the physician to make a correct diagnosis.

For a long time past, it has been known that electrical changes take place in muscles, whenever muscular work is done; and this is true of the heart—a great muscular organ. The heart pumps the blood through the arteries, then into the tiny little vessels called the capillaries—so small that they are visible only under a microscope—and then into the veins, by which it is returned to the starting point. With every heart-beat, there is a certain discharge of electricity—very faint, it is true, but still present. By means of a delicate and ingenious apparatus, lately invented, it has been found possible to measure the electric changes which occur with every heart-beat, and in this way to arrive at an exact method of measuring its equality, and other facts connected with it, which have long withstood all efforts to discover their nature.

GETTING A TRIAL BALANCE OF THE BODY.

There is another very important and interesting achievement in modern medical science. It is generally believed that the food we eat supplies us with heat and energy, and that it also replaces the tissues which are worn away by the muscular and other work which we perform every day. When one walks a mile, he destroys a certain amount of the substance of the body; it is broken down, and the food one eats must replace it. One of the most difficult problems in medical science has been to give the proper amount of food to the body, neither too little nor too much, to maintain this balance. The weight of the body can be measured, more or less accurately, by means of scales; but other questions, however, are more difficult. But a special room has now been constructed, called the ''respiration calorimeter'' (from *calore,* the unit of heat). A man is placed in this room, which can be hermetically sealed. All his food and drink are weighed and measured; the air is analyzed, both before it enters the room and after it leaves it; all the products and excretions of the body are taken account of; and in this way it is possible to measure exactly what goes into the body of the subject, and what passes out of it. Thus record is made of the loss or gain in weight; readings with the thermometer indicate the degree of bodily heat; and the amount of work which the patient does in this closed-in room, indicating the amount of energy employed in muscular work, can also be measured, and so also the amount of vitality supplied to the body, and expended by it. The body is put in a balance, as it were. On the one side, is the food, the drink, the air, etc., supplied to it; on the other hand, the weight, the heat, and the energy expended. And the two will be found to agree; the scales balance. In this way the proper amount of food for special kinds of work can be accurately measured.

THE MICROSCOPE IN MEDICINE.

The microscope, too, has been of very great value in all branches of medicine. The body itself is composed of innumerable tiny cells, which divide and subdivide, and which often become diseased. The microscope enables us to watch, not only the normal growth of these cells, but their changes and diseases; and so to treat them. By its aid, also, the bacteria which invade the body can be seen and studied. Indeed, the science of bacteriology depends upon the microscope.

HOW TO TELL WHEN ONE IS AFRAID.

One of the most interesting methods of diagnosing abnormal conditions is by means of a weak electric current passed through the body. The instrument is called the galvanometer, and consists simply of an electric needle, which records the variations in a weak electric current. When certain emotions are present, such as anger, or fear, for instance, the needle of the instrument registers a certain current; when other emotions are present, other variations are noted. This device has been employed, with great success, in criminal cases. A number of questions are asked the criminal, some of which contain words more or less directly bearing upon the crime committed. Although the criminal may show no outward emotion, his inner mental state of fear is recorded by means of the electric instrument; and in this way he is detected. It is hoped that, in the future, this instrument may be found very useful in courts of law.

INSTRUMENTS THAT HELP US TO SEE AND HEAR.

Then, too, there are instruments for aiding defective hearing and sight. We hear by means of air waves, and the vibration of a small membrane within the ear, called the ear-drum. When the air-waves strike upon this little parchment-like drum-head, they cause this to vibrate, and this vibration is carried along certain nerves to a group of brain cells, wherein the sense of hearing is manifested. In old age, however, and in certain diseased conditions, this drum-head will not vibrate properly; it seems to the patient as though the air-waves are not strong enough, though, as a matter of fact, the fault lies in the inability of his ear to magnify the sounds sufficiently. So physicians have invented instruments called ear-trumpets, varying in size and shape, which magnify the sounds.

In the same manner, instruments have been invented for helping the eyes. We see things because light-rays coming from an object strike the eyes, pass into and through them, and then along certain nerves, to the back of the brain, where the sensation of sight is produced. Things are not visible in themselves; for, if they were, we should see them in the dark. But sometimes the ball of the eye gets bent out of shape, or its interior disarranged, so that it will no longer receive the light rays as it should. In that case, instruments must be devised to help the eyes along. These instruments are lenses, which bend the light-rays to suit the eye, and in other ways assist it. So the science of optics, as used and applied in medicine, is of great assistance.

About a hundred years ago, an experimenter was holding a cat under water, in the course of some experiment, and noticed, with surprise, that the eyes of the cat no longer appeared black; he could see into them. He was led to experiment, from this, and found that the water, by diverting the light-rays at a different angle, caused this result. He then tried other experiments, and the upshot of this accident was the invention of the opthalmoscope, an instrument by means of which the interior of the eye can be examined. This is the instrument which one will see used by the optician, when the eyes are examined; and by its aid he is enabled to look right into the eye, and tell whether or not it is healthy inside.

THE X-RAY AND ITS PROMISE.

Another invention has come into the field, which is so important and promises so much for medical science, that a more extended description must be given.

The X-rays are peculiar radiations that are given off, under certain conditions, by glass bulbs (known as "vacuum tubes") from which nearly all the air has been removed. Each of these bulbs or tubes contains two electrodes, and wires leading to the electrodes are sealed in through the glass. When the electrodes are connected to the poles of a powerful induction coil in action, and the vacuum in the tube is sufficiently perfect, the tube shows charactistic appearances in the dark. It various parts shine with a soft light, but the most noteworthy feature is a luminous beam or "ray" that extends across the bulb from the negative electrode, and which, from the fact that it starts from this negative electrode (or "cathode"), is called the "cathode ray."

MEANING OF THE NAME.

Hittorf, Crookes, Lenard, and others, experimented with the cathode ray in vacuum tubes of this sort, and obtained many interesting results; but it was reserved for Wilhelm Konrad Röntgen, in 1895, to discover that an invisible and previously unknown kind of radiation is given off from the tube. Pending further investigation respecting the nature and relations of these rays, he provisionally called them "X-rays," from the fact that the letter "*x*" is used, in algebra, to represent an unknown quantity. The exact nature of these rays is still a mystery in spite of all the work that has been spent upon them.

SOURCE OF THE X-RAYS.

When the cathode ray, after proceeding across the tube, impinges against the glass wall of the tube, the spot where it strikes is luminous, and it is also the source from which the invisible X-rays emanate. A more intense effect can be obtained by shaping the tube so that the cathode ray strikes upon the anode, or positive electrode of the tube, which then becomes the source of the X-rays.

PHOTOGRAPHIC AND FLUORESCENT EFFECTS.

Although X-rays are not capable of directly affecting the human eye (or, at least, of affecting it more than faintly), they act quite strongly upon the photographic plate, behaving in this respect like ordinary light. The image that they produce is not immediately visible, but it comes out after development in the usual way, and with the usual chemicals. X-rays are also capable of causing certain chemical substances to shine with a phosphorescent or fluorescent light, and screens (called "fluorescent screens") coated with these sensitive substances are used to make the presence and behavior of the rays evident to the eye.

SHADOW PICTURES.

The practical utility of X-rays depends mainly upon the fact that they are far more penetrating than rays of ordinary light. When the human hand is held between an X-ray tube and a fluorescent screen in a dark room, the X-rays penetrate the fleshy parts of the hand very freely, but they are somewhat obstructed by the bones, and the result is that a shadow-picture of the bones of the hand is seen upon the screen, with the flesh outlined about them only faintly. With a suitable apparatus, the interior structure of the bones themselves may even be roughly made out in this way, the denser parts of the bones obstructing the rays more completely than the spongier parts, and hence giving darker markings on the screen.

It is easy to understand that the X-rays are often of great value in surgical cases, both for examining fractures and dislocations of the bones, and also for definitely ascertaining the positions of foreign bodies, such as bullets.

When the trunk of the human body is placed between a powerful X-ray tube and a fluorescent screen, certain of the firmer and more opaque internal organs can be distinguished by an experienced observer. The beating of the heart may be watched, for example, although the degree of distinctness obtainable in a case of this kind is far less than that obtained in the case of a thinner portion of the body, like the hand.

EFFECTS OF X-RAYS UPON THE HUMAN BODY.

A brief exposure to X-rays is harmless, but prolonged exposure brings about inflammatory effects that are painful and even dangerous. The skin, for example, becomes burned in much the same way as it would from prolonged exposure to a hot, summer sun. Continuous exposure to X-rays for a long period is also likely to give rise to malignant or cancerous degeneration of the affected tissues, but, on the other hand, X-rays have been more or less widely used (with briefer exposures) for the curative treatment of cancer arising from other causes; there is, however, a wide difference of opinion among physicians as to their efficacy.

PHYSICAL NATURE OF X-RAYS.

The X-rays resemble ordinary light in certain respects, while in other respects the two are widely different. Thus X-rays cannot be reflected in the way that light is reflected from a mirror, nor refracted as light is refracted by a lens or a prism; nor do they show any of the phenomena of polarization that are so characteristic of light. In fact they resemble light only in traveling in straight lines, in moving with a speed that is very great (and perhaps equal to that of light), and in affecting the photographic plate. Since they cannot be reflected nor refracted, they cannot give a true *image* upon the fluorescent screen or the photographic plate—the only pictures that they not give a true *image* upon the fluorescent screen or those that ordinary light would produce, of an object that was more or less transparent.

According to Maxwell's views (which are now widely held by scientific men), ordinary light is a rapidly periodic disturbance of an electrical nature, in the ether; and it is considered probable that the X-rays are likewise electrical disturbances of the ether, but that they differ from light in not being *periodic.*

PART IV.

Discoveries and Inventions for Extending Man's Efficiency and Power.

CHAPTER XXXIV.

Iron, a Most Useful Metal.

THINGS THAT ARE TAKEN AS A MATTER OF COURSE.

SOMEONE has said that the commonest things are least understood. In the same vein we may say that the most useful things are least appreciated. It so happens that whatever is constantly before our eyes and continually ministers to our wants is taken as a matter of course; we neither know nor care to know anything about it. But if we did stop to consider the common things around us, what a world of new interests they would reveal.

How many of us know how iron, for instance, is made? Yet it is one of the commonest and one of the most useful metals known. So important a factor of industrial and general development has iron been in the life of mankind that it has been called "the metal of civilization."

IRON, IRON, EVERYWHERE.

It is impossible to name all the articles that iron enters into, nor can the things made wholly of it be enumerated. Iron is so readily cast into any shape that almost anything can be made of it. It can be rolled into sheets, cast into blocks, drawn into wires, sharpened into swords, and beaten into plowshares. It will take any form and serve any purpose, from the smallest nail to the biggest machine. Frames for buildings, cars, engines, steamships, locomotives, pipes of all dimensions, tools of all kinds, machinery of every description, ocean cables, telegraph and telephone wires, entire structures, and even furniture—these are but a few of the varied uses to which iron, in one form or another, can be put. And who could not think of as many more? The pen one writes with, the clock he looks at, the knife at his elbow, the steam pipe which keeps him warm, the gas fixture that supplies him with artificial light, and parts of his very desk—are all products of iron. Look out of the window or down the street, and observe how many iron things meet the eye everywhere. In one form or another, iron is never out of sight. Why, we even drink it as medicine to make us well or as a tonic to improve our blood. It would take a chemist to enumerate them all, and even then the presence of iron in these compounds would never be suspected from the Latin names that scientists give them. In short, the world is full of iron, and it is hard to imagine how men could ever get along without it.

THE AWFUL COST OF IRON.

Going back as far as possible in recorded history, no time can be found when iron was wholly unknown. The pyramid builders of ancient Egypt used it, and Moses in the Bible speaks of "furnaces for melting iron." The Romans mined it extensively during the fifth century in England (which, you may remember, they then held as part of their great Empire), and European countries have never neglected it since. Down to the close of the sixteenth century, however, the smelting and use of iron were greatly limited by the supply of fuel necessary for its manufacture. Till then, wood was the only fuel available for the purpose, and it required so much of this to make iron that entire forests were consumed in the process. For instance, to produce one ton of iron, many thousand cords of wood were required and as forests do not grow overnight, no country could stand such ravages indefinitely. We find England, for example, fully apprehensive of the great danger of forest exhaustion, passing a special law in 1581 that made it a penal offense to erect new ironworks in certain districts or to enlarge beyond prescribed limits those already existing. Other countries found similar prohibitions necessary. Of course, the production of iron was greatly restricted by such laws. Some ironworks had to be removed, while a number of large plants were closed altogether.

It was not until 1610, when a certain German, Simon Sturtevant, discovered how to use coal in the making of iron, that the iron industry took rank as one of the most important in the world. From Sturtevant's discovery, with the numerous improvements in the process of iron-making that soon followed, dates the rise of our modern iron industry, which has appropriately designated the last three centuries as "the Iron Age."

A SIDEWALK AROUND THE WORLD.

In many lands, whose people have not yet learned the art of extracting ore and turning it into iron, the business of mining this metal is not profitable. But all civilized countries mine more or less iron. The United States ranks first, Great Britain second, Germany third, France fourth, with Norway and Sweden fifth.

In the United States alone more than thirty million tons of iron ore, worth over $60,000,000, are annually mined. To form a slight idea of the enormous quantity this makes, an illustration may help. "If we were to construct a sidewalk two inches thick and six feet wide out of one year's production," says a writer who has taken the trouble to figure this out, "it would reach more than half way round the world. . . . If we were to do the same with the world's entire production, the sidewalk would stretch nearly three times as far—all around once and half way around again."

While iron mines are widely distributed in the United States, they are most abundant in a few regions. Perhaps the richest deposits in the world are found around Lake Superior, in the States of Michigan and Minnesota; these yield three-fourths of the entire output of the United States. Rich beds of iron ore are found also in the Appalachian Mountains, in Pennsylvania, West Virginia, Alabama, and Tennessee. From a single mine in the Mesabi Range two million tons of ore are extracted every year, an amount equal to the total production of Sweden. Five mines in the same range yield more iron annually than is mined in the whole of France. The Lake Superior ore beds yield as much as fifteen million tons a year, while the Mesabi Iron Mountain is estimated to contain at least five hundred million tons of ore.

Reckoning in, also, the number of immense iron ore beds in China, Russia, Siberia, Australia, and Africa, which are practically untouched, what a supply of iron piles up in the imagination! Verily, this is the "Age of Iron."

TRANSPORTATION—THE SHOVELS AND CARS.

Due to its great weight, the cost of handling and transporting iron ore is quite considerable, and it is a constant concern with mining companies to reduce this expense to the minimum. The special devices used in the United States are so far superior to those of any other that the resulting economy enables it to produce iron—and, of course, everything made of iron—cheaper than is possible anywhere else in the world. These methods are most interesting.

To begin with, the iron ore is loaded directly from the mines, or beds, by giant steam shovels, weighing about ninety tons, costing about $10,000 each, and lifting five tons at every scoop. It takes but five scoopfuls to fill a car. One such machine, under favorable conditions, has been known to load two hundred and thirty-three cars of twenty-five tons' capacity—a total of nearly six thousand tons of ore—in nine hours. Think what a mountain is thus lifted! Yet only ten men are required to handle this huge steam shovel.

A dozen or more twenty-five-ton cars are run alongside a steam shovel and pushed by a locomotive as fast as the shovel can load the cars. These cars are immediately made up into trains and sent speeding on their course, while other cars are being made ready for other trains; and the next day—possibly the same day—a second or a third train of perhaps fifty cars leaves the mining fields. Their destination may be some port on Lake Superior, for instance, where the ore is docked with equal expedition. And while one locomotive is feeding cars to a steam shovel, another is busily coupling a train of ''empties'' soon to replace those drawn out. A ''continuous performance'' indeed, for the work never halts until the day is done or the mine becomes exhausted. But let us now visit the docks.

INGENIOUS DUMPING AT THE DOCKS.

The method of unloading the ore at the docks is not a whit less wonderful than that of loading at the mines. The cars in which the ore is transported are so constructed as to make unloading almost automatic. One type of car has a bottom which can let its contents fall right through, when a certain attachment is worked; another can very easily be tipped over and dumped. The docks, forty or fifty feet high and approached by a gentle grade, are essentially like the coal docks that are a familiar sight on wharves. Directly under the tracks are the storage bins, or ‘‘pockets.’’ When the train is in place, all that need be done to unload its cars is to open their trap doors or tip and dump them, according to the style of car. Could anything be simpler? Little wonder that the ore is so cheap at the docks.

RELOADING ON STEAMERS.

When this ore is to be re-loaded for shipment to iron works, special mechanical devices are again brought into play. Shutes leading directly from the ‘‘pockets’’ are opened, and the ore slides down of its own accord. As most of the ore docks are in lake regions, it is found more economical to ship ore to iron factories—also on a lake or river, as a rule— by steamers, most of which are specially constructed for iron-carrying. The capacity of some of the steamers is from five thousand to ten thousand long tons, yet it takes but little time to load them.

HOW ‘‘PIG IRON’’ GOT OUT OF THE ORE.

Everybody knows that iron is not found in the mines in a free state—that is, free from other substances. The only naturally pure iron comes from the sky in the form of meteorites. To extract the iron metal from the ore intense heat, and hence much coal, is necessary; therefore, iron factories are usually situated in coal regions. The process of smelting, which is the first process of separating iron from its impurities, is very interesting. It is done by means of a blast furnace, an iron structure from forty to a hundred feet high, lined with special brick—appropriately called ‘‘fire-brick’’—that can bear extreme heat. Into this furnace are put coke, ore, and limestone. The coke, of course, is for fuel; the limestone absorbs all the impurities which are liberated by the heat. Both limestone and impurities together form a layer called ''slag,'' which flows out through an aperture in the furnace. To increase the intensity of the coke fire, itself much hotter than any coal fire, a strong current of hot air is forced continually under it. This is technically known as ''blasting,'' the air current being called the ''blast.'' The molten iron drops of its own accord to the bottom of the furnace.

After the slag has been released workmen open a lower door and clear away the iron, which has already cooled and hardened near the opening. Thereupon the molten metal pours out, ''like a display of Fourth-of-July fireworks,'' in a stream of liquid fire, which flows into trenches called ''pigs''—hence ''pig iron''—where the metal is allowed to cool in bars of two or three feet in length and three or four inches in diameter.

FROM PIG IRON TO CAST IRON.

When this ''pig iron'' is taken to the iron foundry, it is melted again, in order to refine it. The purer metal produced by this process, running into molds, forms all the articles we call ''cast-iron''—tools, pipes, hydrants, stoves, machinery, and a thousand and one other things. All such articles are very cheap, because they are so easily shaped or cast, the liquid iron readily taking the form of the mold into which it is poured, just as water or any other liquid assumes the form of its container.

FROM CAST IRON TO OTHER KINDS.

But things made of cast iron are exceedingly brittle, and cannot readily be mended when broken. Hence the need of another process of refining, which produces a purer grade of the metal, called ''wrought iron.'' This kind of iron is much softer than ''pig'' and can be mended without difficulty. Everything that must stand bending, such as the better kind of nails, are made of wrought iron.

A still finer quality of iron, called ''bar iron,'' results from further purification. This grade of iron is quite malleable, that is, can be beaten out with a hammer, forged, or even tempered to a considerable degree. Horse-shoes are one of the familiar articles made from bar iron. It is the purest and best kind of iron produced—in quality approaching that of steel, which is really only another kind of iron.

THE "IRON CITY."

That iron is a most important commercial product can be judged from the industrial standing of the cities engaged in its manufacture. These are Pittsburgh, the greatest "Iron City" in the world; then, in about the order named, Chicago, Birmingham, Ala., Cincinnati, Baltimore, Cleveland, Philadelphia, Wheeling, and New York. There are very few American (or European) cities of any size possessing water-transportation facilities that do not have iron-works on their list of industries. But Pittsburgh is the master of them all!

This city enjoys not only unusual transportation facilities both by land and water, but has the added advantage of being able to use for fuel the natural gas so abundant in its vicinity. Situated on the Ohio River at the junction of the Allegheny and Monongahela Rivers, as well as near Lake Erie, Pittsburg's water connections are unexcelled by any city in the United States. Moreover, the Mississippi River furnishes other thousands of miles of waterway and gives access to many other States, finally reaching the great Gulf itself. Millions of tons of ore and pig iron reach Pittsburgh by water through what is known as the Great Lake Route. As if this were not enough, fourteen railroads enter the city. Is it any wonder that Pittsburgh, with its tall chimneys steadily pouring forth clouds of smoke from red-hot furnaces, holds first place in the world among cities engaged in the iron and steel industries?

Many plants run continuously, night and day, turning out cars, engines, building material, kitchen utensils, tools and machinery of every description by the hundred thousand!

THE "METAL OF PROGRESS."

What a blessing iron is! To what an army it affords employment and how abundantly it ministers to the needs of man! It has been called "the metal of civilization"; it might just as appropriately be called the "metal of progress and prosperity."

CHAPTER XXXV.

The Wonders of Steel.

THE ERA OF STEEL.

OWING to its greater compactness and malleability, steel is found much more serviceable than the rougher iron out of which it is produced. Its elastic quality renders it invaluable in making springs for cars, carriages, clocks and watches, beds and couches, traps, and hundreds of other articles in common use. Its compactness and strength make it the ideal metal for building steamships, automobiles, locomotives, flying machines, and machinery of every conceivable kind. Its malleability, that is, the property of being readily beaten out or flattened to any desired shape, makes it the great tool metal. From a steel chisel hard enough to cut other steel, to a razor capable of being dulled by wood, the extremes of tempered steel are far apart and numerous. Such common uses of steel as the making of rails, wires, cables, locks, screws, knives and forks, farmers' implements, parts of sewing machines, typewriters, frames for buildings, etc., need hardly be mentioned. In the making of pistols and guns, as well as numerous other weapons of war, steel never had a rival. Indeed, from the minutest watch-spring to the largest steamship, steel has so fully demonstrated its adaptability that its uses are constantly multiplying. To enumerate them all were neither possible nor desirable. One cannot look far afield without seeing this faithful servant of man, ministering to comfort and lightening toil. The era of tools, machinery, and all other labor-saving devices, did not really set in until man had learned the art of making steel.

HOW STEEL USED TO BE MADE.

Various processes are employed in making steel from iron, but only two of them can be considered here. Steel is a compound of iron, carbon, silicon and manganese. The proportion of carbon is very essential. Wrought iron has too little carbon for steel, while cast iron has too much—and all iron contains some amount of carbon; hence steel can be made by either, first, increasing the amount of carbon contained in wrought iron, or second, reducing the quantity in cast iron. Upon this power of increase or decrease depend the two processes of steel manufacture usually employed.

The first method is by far the older, having been used for centuries, and is as simple as it is old. Into a fire-proof box, filled with finely-ground charcoal, are placed bars of wrought iron. The box is then subjected to intense heat for several days, so that the bars, fused together with the powdered charcoal, take up considerable carbon. More carbon usually mixes near the outside than the inside of the bars. Therefore, to expose more of their surface, they are cut into smaller bars, heated again, welded together or fused in crucibles, and finally cast into small pieces of steel called ingots. Such steel is sometimes known as "blistered steel," because the wrought-iron bars are covered with blisters when taken from the fire-box.

AN ENEMY—BUT MOSTLY A FRIEND.

The second process is more recent, having been used for less than a half century, and is rather complicated. To understand it, one must bear in mind a few facts about the chemistry of the atmosphere, which is composed of oxygen and nitrogen. Oxygen is the more active element, and is responsible for the rusting of metals, the decay of fruit, etc. But it is a good servant, too. It makes fires burn, plants grow, purifies our blood, and performs many other useful offices. Whenever oxygen takes up, or consumes, some other element, chemists call this a process of oxidation, and we say things oxidize when they rust, decay, or burn. Now this very active gas has a great affinity for carbon, silicon, and manganese—the very things which, when combined with iron in certain proportions, go to make steel.

A PROCESS THAT CREATED A HOUSEHOLD WORD.

Now comes the ingenious application of this bit of elementary chemistry. It was thought quite feasible that, if iron, which contains both carbon and silicon, were fused into a liquid state and then had a strong current of air forced through it, the oxygen in the air might burn out the carbon and silicon and carry them off into the atmosphere. The man to whom this idea first occurred was Sir Henry Bessemer, an Englishman. He experimented and it worked exactly as he had anticipated. The process was patented in 1855, and has since been known, everywhere, as the Bessemer Process of Steel-making. The discovery proved to be one of the most important ever made in connection with any metal, for it revolutionized the manufacture of steel. With Bessemer's discovery in the middle of the last century we may date the beginning of the Age of Steel.

A WONDERFUL ART AND A BEAUTIFUL SIGHT.

The method itself may be described as follows: To begin with, a large pear-shaped vessel, called a "converter," whose greatest diameter is eight feet and usual height fifteen feet, is pressed into service. This vessel must be both strong and fire-proof to withstand terrific pressure and extreme temperature. It is lined with fire-brick, and is suspended from pivots, so that it may be tipped over easily from a vertical to a horizontal position. A mass of molten iron is run into this converter, and through a number of perforations in its bottom a current of air, as strong as four thousand to five thousand horse-power engines can produce, is sent up. The air thus forced through the molten metal expands, its oxygen combines with the silicon, while sparks issue from the mouth of the converter. Strangely enough, the carbon is not touched by the oxygen until all the silicon is consumed—as if the greedy oxygen liked silicon best. When the oxygen attacks the carbon, the sight is most beautiful. A brilliant flame issues from the mouth of the converter, accompanied with a roar so terrific that even lions might be awed by it. When the din and pyrotechnical display are over, the blast is shut off. The iron has been freed from its carbon and silicon, but has not yet become steel.

Carbon, silicon, and manganese, mingled in the right proportions, must now be placed in the converter. The whole is then subjected to another violent process, and the compound called steel has been produced. It is only necessary to add greater or smaller quantities of carbon in the last process to produce steel of varying degrees of hardness. The entire process of converting iron into steel does not take, under ideal conditions, more than fifteen minutes, but this depends largely upon the force of the blast and the quality of the metal employed.

WHERE TEMPER IS A VIRTUE.

The steel—"Bessemer steel" this product is called—is now ready for use, save for a little tempering which is usually necessary. Tempering simply means giving the metal its proper degree of hardness or softness. Every tool must have its peculiar temper, depending upon the purpose for which it is intended. We do not greatly admire a person who has "a temper," it is true; but with tools the temper is a virtue. Tempering steel is a simple process. If it be heated to white heat and then plunged into ice-cold water, the hardest steel known results. But if, on the other hand, the hot steel is allowed to cool gradually, the softest possible steel is produced. Between these extremes lie all possible degrees of hardness and softness, and it is imparted by merely varying the amount of time allowed for cooling the overheated steel. It is this property of steel—and Bessemer steel especially—that makes it so well adapted to the great number of uses for which the cruder, bulkier, and less malleable iron is nowadays unsuited.

WHAT WONDERS STEEL HAS WROUGHT.

It has already been mentioned that, as a maker of tools and machinery, steel has no rival. It is, indeed, the material that supplies most of the instruments of labor. Upon the quality of the tool frequently depends the quality of the work done, and a number of inventions could not have been applied in the absence of mechanical capacity—fine tools, machinery, and all instruments of precision—to put the ideas of the inventor into practical effect. Without modern machine-tools, all our wonderful architectural, mechanical, and engineering feats would be absolutely impossible.

So long as iron was the sole metal available for such purposes, no construction requiring perfect exactitude could be undertaken. With the discovery of the more malleable steel, and the practical processes for turning it into tools and machinery of every sort, came the new era in modern industry whose importance we are too prone to underestimate. The execution by machinery of work previously done by hand—if done it could be at all—has meant much more than mere economy in time and labor, great as these are. It has rendered possible dozens of new industries that are now vital elements of what we call civilization.

What has not steel done for us in perfecting the locomotive, the steamship, the steam-engine, the weaving loom, the printing press, the harvester, the automobile, and the flying-machine!

THE STEEL CITIES OF THE UNITED STATES.

Nothing shows so well the importance of steel in the modern world as the number of large cities engaged in the steel industry and the millions of workmen it affords remunerative employment. Dozens of cities in the United States and Europe owe much of their prosperity, if not their very existence, to the steel industry.

Some steel cities are Pittsburgh, Chicago, Johnstown, Pa., Buffalo, Baltimore, Allegheny, Reading, Scranton, Duluth, Rochester, Syracuse, Albany, Troy, New York, Philadelphia, Wheeling, W. Va., Roanoke, Va., St. Louis, Wilmington, Del. In these and many others steel and steel articles of every description can be produced cheaper than in any other country. Philadelphia alone supplies the world with more warships and locomotives than any other city in either hemisphere.

More than two thousand first-class locomotives is the average annual output at Baldwin's famous locomotive works, and it takes thirty thousand men, working day and night, to do it. Cramps' ship yard, the other great steel plant in Philadelphia, is equally busy turning out battleships faster than it can be done anywhere else.

STEEL IN OTHER COUNTRIES.

Next in rank to the United States as a steel-producing and machine-making country, come Germany, Great Britain, France, Russia, Italy, Spain, and Belgium—somewhat in the order named. Each of these flourishing cities marks the respective centers of their steel industries; in each, millions of workmen are dependent wholly upon steel and its products for their means of subsistence.

But no city can compare in this respect with the town of Essen, in Prussia, which contains the largest single steel and iron plant in the world. This town had but a few thousand inhabitants before steel and iron works were established there. It now has more than sixty-eight thousand people engaged in some branch of the steel industry. If we multiply this by four (on the assumption that one workman supports on an average three other persons), we find that more than two hundred and fifty thousand people subsist at Essen directly through the steel and iron industry. This number itself—a quarter of a million—would fill such large cities as Newark, St. Paul, or Washington. Of course, the number of merchants, tradesmen, etc., who depend for their custom or trade upon the army of steel and iron workers, must be also very large. Add to this the numerous surrounding districts engaged in coal and iron mining which feed the great plant at Essen, and one finds a huge army of men—surely a million persons—employed, directly or indirectly, by this one factory in Prussia.

THE GREAT KRUPP WORKS.

Krupp's Iron and Steel Works at Essen had their origin in a small iron forge established at Essen, in 1810, by Frederick Krupp. From this humble beginning his successors, despite many adverse circumstances, have gradually built up the present colossal steel industry. More than five hundred acres are occupied in the town of Essen by this enormous plant—not to speak of the subsidiary industries of mining coal and iron in its vicinity. There are more than a hundred steel hammers, some weighing as much as fifty tons, fifteen Bessemer converters, seventeen hundred furnaces, about six hundred steam engines capable of developing a total of ninety thousand horse-power, and twenty-five rolling trains, in this giant plant. Its furnaces alone burn more than three thousand tons of coke and coal every day, while the entire works consumed in one year two million, four hundred and ninety-one thousand, four hundred and six tons of fuel. And the busy work, with the sixty-eight thousand workmen, never halts, except on Sundays and a few holidays.

In addition to the vast equipment needed within the Krupp plant, a separate railway system, with eighty-seven miles of track, fifty-three locomotives, and two thousand three hundred and ninety-six cars, has been found necessary without. The plant has also its own electric equipment, a printing office, a book-bindery, chemical laboratories, photographic and lithographic studios, and a gas plant producing about sixty million cubic feet of gas. What a multitude of enterprises are made possible and necessary by this one iron and steel factory! Surely a million people was a conservative estimate of the number who, in one way or another, reap the vast benefits of the steel works at Essen. Is it any wonder that this Prussian town should have been named "the steel city?"

ARTS OF PEACE AS WELL AS WAR.

Contrary to the prevailing idea, that associates the name of Krupp with the manufacture of guns and other instruments of destruction, two-thirds of the articles produced in the Krupp Steel Works are intended for peaceful uses. It is true that the guns and cannon made at Essen are unequaled anywhere else in the world. But Krupp's Works manufacture everything that can be made of steel, from the parts of a locomotive to mint-dies, with such accuracy and precision as never have been surpassed even in the watch-making industry. Moreover, this plant produces the finest steel known to modern manufacture. The Krupps can make homogeneous blocks of steel weighing seventy-five tons or more which, when broken across, reveal no flaw anywhere, even under a microscope—a rare achievement in steel-making. Not only is such steel of marvelous uniformity, but of unusual strength as well, having been known to withstand the tension of forty tons to the square inch—another notable distinction in Krupp steel. All this is made possible by exact and rigid tests of every piece of material used in manufacture, the standards being fixed with special reference to the purpose for which the metal is ultimately to be used.

CONSIDERATION AND CO-OPERATION.

Perhaps one reason for the unprecedented success of the Krupp firm has been its scrupulous care for the welfare and comfort of its employees. The ''Steel City'' of Essen contains multitudes of small dwellings specially constructed to meet the needs of its workingmen, and these were all erected by the Krupps. The same solicitude for their employees was shown by the establishment of schools, hospitals, parks, museums, theaters, and libraries. Sick relief and pensions are regular features of an organization to which every one of Krupp's employees must belong. Special arrangements are made also for life insurance at low-rates. But the most important institution at Essen, promoted as all others by the far-sighted steel masters, is the Central Supply Store. This is a coöperative institution, owned by the Krupps, where all general merchandise is sold at cost. About thirty branch stores in various parts of the town, connected with the central store, place the advantages of this coöperative system within the reach of all. The ‘‘City of Steel’’ evidently tastes much of the milk of human kindness. And all this is but one of the accessories of the steel industry.

CHAPTER XXXVI.

Steam Boilers.

STRENGTH OF BOILERS.

THE steam boiler is an apparatus for generating steam under pressure, either for running engines or for heating purposes. Heating boilers, which are operated at very low pressures, are often made of cast-iron; but boilers used for generating steam for power carry pressures that may be as great as one hundred and fifty pounds on every square inch of surface, and are built mostly of steel plates and tubes.

High pressure boilers are subject to great stresses, and they must be designed and built with strict regard to this fact. The pressure that such a boiler is to carry is determined by the nature of the work that is to be done; the stress that will come upon every part of it must be calculated, and every part must be proportioned accordingly. It would not do to make the boiler only just strong enough to hold together, however, because a little excess of pressure, above that anticipated by the builder, would then cause an accident. To prevent this, everything is made, we will say, five times as strong as the calculation requires, and the factor (five, as we have here taken it to be) by which the strength of each part is thus increased, is called the ‘‘factor of safety’’ of the boiler. This factor of safety is intended to cover all the uncertainties that may exist in the materials and the workmanship, and for this reason it has been humorously called the "factor of ignorance," because it provides for all the things that we don't know. It is much more than a mere factor of ignorance, however. Like all other metals, steel begins to take a permanent stretch long before it becomes strained to the point of immediate breakage, and one important use of the factor of safety is to keep the stresses in the plates of the boiler below the point at which such stretching would begin.

Boilers are made in many forms, and one type will be found prevalent in one country, and another in another—no doubt because the course of development of steam engineering in the various parts of the world has happened to follow slightly different lines.

ACCESSORIES.

Every boiler is provided with certain accessories that serve to make its operation reasonably safe. For example, each should have a pressure gauge, so that the pressure of the steam that it contains can be read off at any moment, and each must also have some kind of a water-gauge for showing how much water the boiler contains.

SAFETY-VALVE.

Each boiler must likewise have a safety valve, which will open automatically when the pressure reaches a value that it would be unwise to exceed, and thus prevent a further accumulation of pressure by letting some of the steam escape into the air. In the old days a safety-valve always consisted of a sort of disk of metal, placed over an opening in the boiler and held down by a weight. Reckless engineers would sometimes hang extra weights upon it, when they wished to run the pressure up for some purpose. In the palmy days of steamboating upon the Mississippi river, when there was keen competition among the fast boats, so that any one of them would take large chances rather than permit its rival to pass it upon the river, it is said that the boilers of the racing steamers were sometimes fired with hams instead of wood or coal; and there is another old saying to the effect that the safety-valve was weighted down, upon such occasions, by hanging a colored man on it!

At the present day it is more common to use what are called ''pop'' safety-valves. These are kept closed by powerful steel springs until the pressure rises to the point at which they are to blow off, and then they open quickly with a kind of popping sound, from which their name is derived.

SCALE.

In service, a thousand things can happen to a boiler to make it unsafe to run. Among these is the accumulation, upon the inner surfaces of the boiler, of a hard, stony deposit known as ''scale.'' This comes from the mineral matter that is dissolved in the water that the boiler evaporates. The quantity of scale deposited in a given time varies widely, according to the locality and the nature of the water, and a careful engineer will see to it that his boiler is cleaned out as often as may be necessary, so that the scale cannot accumulate in it to a dangerous degree.

BOILER EXPLOSIONS.

Boiler explosions are all too common, especially in the United States, where we have something like five hundred of them every year. The number that occur in England and in Germany is far smaller than this, and the difference cannot be accounted for by assuming a larger number of boilers to be in use here, nor by assuming that our explosions are made public more systematically. The real reason lies deeper, and is not fully known.

It is a common belief that a boiler cannot explode unless the water in it becomes low. Advocates of this theory point out that the plates of the boiler can become red-hot when they are not covered by water, and they claim that when more water is pumped in, under these circumstances, it strikes these red-hot plates and flashes suddenly into steam, with the production of a tremendous pressure. Now there can be no doubt about low water being dangerous, nor any doubt that it can produce an explosion; and yet it is a fact that explosions that are positively known to be due to this cause are never really *violent*. The most disastrous ones are those that occur when the boilers contain an abundance of water.

THE SULTANA EXPLOSION.

When a boiler does explode disastrously, the damage that is wrought is sometimes very great, and there is often a heavy loss of life also. The worst boiler explosion in history, so far as regards loss of life, was the one that destroyed the Mississippi river steamboat *Sultana,* on April 27, 1865, near Memphis, Tenn. The *Sultana* was loaded down with soldiers who had been released from Southern prisons, and the explosion sank her, and caused the death of 1,238 persons.

CHAPTER XXXVII

Steam Turbines.

HOW A TURBINE DIFFERS FROM AN ENGINE.

THE steam turbine, like the steam engine, is a device for developing mechanical power by the action of steam. In the steam engine the steam is confined within a cylinder or some other equivalent receptacle, from which it cannot escape without pushing a piston before it, and so doing work. In the turbine, however, the steam is not confined in the same positive manner, but is allowed to blow against or between a lot of vanes that are attached to a movable wheel or cylinder, mounted upon an axle. It is plain that if a powerful stream of water from a hose were caused to play upon a set of vanes in this way, a sensible amount of power might be developed, although the device would certainly be a wasteful one, unless it were designed in accordance with scientific principles. But it is by no means apparent, at first sight, that any considerable quantity of mechanical effect could be obtained by merely blowing jets of steam against vanes in the same way. Branca, centuries ago, devised a motor operating on this principle, and yet it is only within the last few years that engineers have found out that a really efficient generator of power can be constructed upon his plan. The plan is now in practical use, however, and the machines that are based upon it are called ''impulse turbines.''

REACTION TURBINES.

The energy of escaping steam may be utilized to generate power in still another way, as will be understood by observing the piece of fireworks familiarly known as the ''pin-wheel.'' When the fuse of the pin-wheel is lighted, a jet of hot gas from the burning powder is blown out, violently and continuously, in a direction at right angles to the axis of the wheel, and the reaction due to the rapid escape of this gas causes the wheel to revolve swiftly in the opposite direction. Steam turbines operating upon this principle are now in general use, and it has been found that they are capable of generating mechanical power quite efficiently. Since they make use of the force of reaction of the escaping steam, they are called ''reaction turbines.'' It is interesting to note that the first turbine to operate upon this principle was constructed by Hero, about the time of, or even a century or two before Christ. In the form that he gave it, however, it was nothing but an instructive toy, and its real commercial possibilities have only recently been seen and developed.

THE IMPULSE TURBINE.

The impulse turbine devised by Branca, and the reaction turbine invented by Hero, were not efficient machines, because they used steam of very low pressure, had but few points at which the power was exerted, and were not designed with the slightest reference to the behavior of steam when expanding from a nozzle or through a set of vanes. In designing modern turbines, the greatest attention has been paid to every detail that might influence the efficiency of the machine, and an immense amount of study and experiment has been required, in order to develop their possibilities as practical generators of power. Some of the commercial forms now in use have thousands of vanes and passages, each of which contributes its mite towards the total power that the machine produces, and the result is, that the efficiency they yield compares very favorably with that shown by the best of the steam engines of the older types.

The impulse turbine may be designed either as a "single-stage" machine, or as a "two-stage" machine. In the single-stage form there is but one moving wheel, carrying a single row of vanes, or blades, to receive the impulse of the steam. A series of nozzles is provided for discharging the steam against these blades, the form of both the nozzles and the blades being very carefully determined by a combination of theory and experiment. The best known single-stage impulse turbines are De Laval's. These make from ten thousand to thirty thousand revolutions per minute, the high speed being requisite in order to obtain a satisfactory efficiency. In the two-stage form of the impulse turbine, there are two sets of nozzles, and two wheels with vanes or blades. The steam passes through the first nozzles and strikes against the first series of blades, but in doing so it is not permitted to expand as completely as in the one-stage machine. Having traversed the vanes on the first wheel, it then passes through the second set of nozzles and strikes upon the vanes of the second wheel, where its expansion is completed. The action may be compared to that which occurs in the ordinary compound steam engine, where the expansive power of the steam is utilized partially in one cylinder, and partially in another. The Curtis turbine is the most familiar impulse machine of the two-stage type.

COMBINATION TURBINES.

Machines that operate upon the reaction principle usually make use of the impulsive effect of the steam also, and hence they may be called ''impulse-and-reaction'' turbines, or ''combination'' turbines. The Westinghouse-Parsons machine is of this type. It consists of a long rotating spindle, or ''rotor,'' considerably larger at one end than at the other, and having on its surface thousands of little blades that are set at an angle with the length of the rotor. A casing fits around the rotor, and to its internal surface another series of blades are secured, the rows on the casing coming between those on the rotor, when the machine is assembled. The steam flows along the length of the machine, between the casing and the rotor, and, in its passage through the multitudes of vanes or blades, it communicates a rotary motion to the spindle or rotor.

THE TURBINE ON STEAM VESSELS.

The efficiency of the steam turbine, as it is now built, is high, but it varies with the amount of work that is being done, and is greatest for the particular load for which the machine is designed. The turbine is especially valuable wherever a high speed is required, and the load is fairly constant; hence it is in special favor in electric-lighting plants. It has also been tried with success upon ocean steamships, and several of the large Atlantic liners are now operated with turbines. There has been much discussion respecting the safety of the turbine for use upon small, high-speed vessels, such as torpedo-boats, because the speed of rotation of the moving parts is so great that severe gyroscopic effects are likely to be produced when the boat makes a turn, and these are likely to throw correspondingly severe strains upon the framework of the vessel. A small turbine-driven vessel belonging to the British navy foundered, a few years ago, under circumstances that led many engineers to believe that her hull was broken apart by the strains to which it was subjected from this cause.

CHAPTER XXXVIII.

Gas Engines.

POWER BY EXPLOSION.

THE gas engine is an engine in which the power that is developed is generated by the explosion, within the cylinder of the engine, of a mixture of air and some inflammable gas or vapor. Any engine in which such explosions are employed for the generation of power is an ''internal combustion engine,'' and the only difference between the internal combustion engine and the gas engine is that in the former the substance that is burned may be gunpowder or anything else that will take fire explosively, while in the latter the fuel is always supposed to be gaseous.

In practice, however, there is little or no difference between the two, as, in most engines that are in actual use, the fuel is either gaseous at the outset, or is vaporized before being introduced into the cylinder of the engine.

The combustible substance, or fuel, that is used in operating a gas engine may be natural gas, coal gas, acetylene gas, or the vapor of alcohol, gasolene, kerosene, or other light mineral oils. In practice, however, producer gas is employed mainly, for the operation of large engines where economy is an important consideration. Many engines are also operated, about iron works, by the waste gases that are given off from the blast furnaces.

Practically all gas engines are single-acting. That is, the cylinder of the gas engine is open at one end and closed at the other, and the explosions which drive the engine take place in only one end of the cylinder. In this respect the design of the gas engine is fundamentally different from that of the steam engine, since, in the latter, the steam is admitted to each end of the cylinder alternately, and power is generated and transmitted to the shaft at every stroke, whether that stroke be a forward one or a backward one. This fundamental difference in design between the gas engine and the steam engine is due to the fact that, in the gas engine, the cylinder is exposed to exceedingly high temperatures, which would make it almost impossible to keep the packing tight around the piston rod, if the forward end of the cylinder were also utilized. The cylinder would be much hotter, too, if explosions occurred in both ends of it.

HOW IT OPERATES.

In the operation of the gas engine it is necessary, first, to introduce the explosive charge into the cylinder; second, to explode it; third, to permit the gases that are generated by the explosion to expand and do work against the piston; and, fourth, to remove the products of this explosion from the cylinder, so that a new charge of gas can be introduced, and the whole process repeated. The methods by which these operations are carried out in practice can be divided into two main classes—one called the ''four cycle'' method, and the other the ''two cycle.'' These names, although they have been adopted so widely that they cannot now be changed, are somewhat unfortunate, because they do not accurately express what takes place in the engines to which they are applied. Properly speaking, a ''cycle'' is a complete round of operations of any kind, of such a nature that, when the thing that is under consideration has performed such a cycle, it has thereby returned to the exact condition it was in when the cycle began. Now a ''four cycle'' gas engine does not (though it might be inferred from the name) perform four cycles between the successive charges of gas that it receives, nor does the ''two cycle'' engine perform two cycles. A four cycle engine receives one charge of gas every four *strokes* that it makes, and a two cycle engine receives a fresh charge every two *strokes.* It would therefore be more correct to describe them as ''four stroke'' and ''two stroke'' engines, respectively.

WHAT OCCURS IN THE CYLINDER.

To understand what occurs in the cylinder of the four cycle engine during one complete cycle (comprising four strokes, or two revolutions), consider it, first, when the piston is as near as it can come to the head of the cylinder, and the cylinder itself is empty. On the next stroke of the engine (which will be *forward*), the piston draws into the cylinder a charge of the explosive mixture that is to generate the power. Then, on the return, or backward stroke, this charge is compressed into a small volume. At or near the end of this return stroke, at a point that varies with the speed of the engine, the compressed mixture is exploded by a flame, an electric spark, or otherwise. A heavy pressure is thereby generated, and the piston is urged forward with great power on its third stroke. The exhaust valve is then opened, and, as the piston comes back on its fourth stroke, it sweeps the burned charge out of the engine. The cycle is then complete, and the operation of the engine consists in the endless repetition of the same process.

In considering the two cycle engine, it will be simpler to start at the moment when the piston has just completed a forward stroke, and is at its most remote position with respect to the back head of the cylinder. The cylinder is now filled with the waste products of the explosion that has just forced the piston forward, and at this moment the exhaust valve opens, and at practically the same time a fresh charge of gas is introduced at the side of the cylinder opposite to the exhaust valve. The incoming charge has been previously compressed somewhat, in another part of the engine, and the introduction of the new charge is so managed that it sweeps the old one out before it. The exhaust valve is then closed, and the piston of the engine, on the backward stroke, compresses the new charge, as before—the ignition and consequent explosion taking place at or near the end of the stroke, as in the four cycle type.

RELATIVE MERITS OF THE ENGINES.

As regards the relative merits of the four cycle and two cycle engines, it may be said that the four cycle type weighs more, per horse power developed, but that it is more readily controlled, more certain in operation, and more economical. The two cycle engine is used somewhat upon automobiles, partly on account of its lesser weight. In marine practice both types are used, perhaps about equally. The two cycle engine falls off more in efficiency, when it is run at a speed higher than the normal speed for which it is designed. It also grows hotter than the four cycle, and hence requires more cooling water.

The heat developed in the cylinder as a result of the explosions is so great that some efficient means for removing a considerable portion of it must be provided, or the engine would be ruined. In large engines it is often necessary to cool every portion of the machine that comes in contact with the cylinder gases, but, in smaller engines it is ordinarily sufficient to cool the cylinder itself. In some engines this cooling is effected by air, but cooling by the use of a water jacket is most common. In the air-cooled forms the cylinder is provided with projecting flanges or pins, to increase its radiating surface, and a blast of air is driven against it by a fan or some equivalent device. The water in the jackets of water-cooled cylinders is continually renewed by a small circulating pump. Fresh water may be used to take its place if, as in marine work, a plentiful supply is at hand. When, as in the case of the automobile engine, the quantity of water is strictly limited, the heated contents of the cylinder jacket are caused to circulate through a radiator that is freely exposed to the air. By this means the jacket water may be cooled sufficiently to be used over and over again.

The proper proportion of gas and air, in an internal combustion engine using gas as fuel, is usually obtained by regulating the size of the admission openings through which the air and the fuel gas enter the cylinder. On some engines the air and gas enter through valves that open automatically when the pressure in the cylinder falls below that of the atmosphere. It is much better, however, to use admission valves that are operated positively by the engine itself, through cams or other devices, and valves of this nature are usually employed upon the larger and more carefully designed engines.

ABOUT CARBURETERS.

Internal combustion engines using gasoline as fuel obtain the correct mixture of air and vapor by means of carbureters. These are made in many different forms, but the purpose of each is to mix a definite quantity of gasoline vapor, or spray, with each charge of air that is drawn into the cylinder.

Three general means are employed for igniting the compressed charge in the cylinder of the engine, these being, first, the electric spark; second, a mechanically operated flame or intensely hot surface; and, third, the so-called ''auto-ignition,'' in which the compression is carried (as in the Diesel engine) to such a high point that the heat thereby generated fires the mixture without other aid. Of these methods the electric one is by far the most common.

The electricity required for electric firing is obtained either from electric batteries (which may be of the primary or storage type), or from a small dynamo operated by the engine itself. Two different ways of applying the electric ignition are employed, these being known, respectively, as the jump-spark method, and the make-and-break method. In either case the electric wires are led into the cylinder through an insulating substance, such as porcelain, to avoid unintentional short-circuiting. (The cylinder itself is often utilized as part of the circuit). In the jump-spark method the two wires, after entering the cylinder, approach each other very closely but do not touch, and by means of a commutator device on the shaft of the engine, a spark is caused to jump across the space between them, at the proper part of the stroke. A spark coil will be necessary in case the electricity is furnished by a battery, but high-tension magnetos may also be had, with which no such coil is required. In the make-and-break method the two wires are continuously in circuit, and their free ends are caused to rub together inside the cylinder, by mechanical means. When the proper instant arrives for igniting the charge, the rubbing ends are separated, and a spark then jumps between them and brings about the desired explosion. On slow speed engines the make-and-break system works quite satisfactorily, but on large engines, and particularly upon those running at high speed, the jump-spark method of ignition is usually preferred.

ABOUT THE JUMP-SPARK.

In engines using the jump-spark, the points between which the spark is to pass are secured to the porcelain insulator through which at least one of the wires enters the cylinder, and the insulator (which, with its attached points, is known as the "spark plug") is so arranged that it can be readily removed. The long-continued passage of sparks between the wire points causes a gradual deposition about them of sooty matter derived from the cylinder charge, and hence it is necessary to clean the spark plug from time to time, or even to renew it entirely when the points become badly burned or the plug becomes short circuited or inoperative in some way that is not easy to remedy.

To regulate the speed of the engine so that it cannot become excessive, four different methods are in use. First, the charge of gas is reduced by partially closing the gas valve; second, gas supply is entirely cut off for one or more complete cycles; third, the exhaust valve is kept open (or closed) during one or more cycles; fourth, the usual charges of gas are admitted to the cylinder, but they are allowed to pass through it, unexploded, until the speed of the engine falls to the normal. The first two of the methods mentioned are the most common. In any of the four cases the regulation is performed automatically, by some device in which use is made of the principle of centrifugal force, or of inertia, to control the valves, or the spark mechanism, when the speed becomes too high.

''THROTTLING GOVERNORS.''

Governing devices which reduce the charge of gas without cutting it off entirely are called ''throttling governors.'' They give very good speed regulation, but are uneconomical, because by reducing the quantity of gas without a corresponding reduction in the air supply, the explosive properties of the mixture are greatly affected, and if the proportion of the gas to the air is altered very seriously, the explosion may not occur at all, and the gas that has been admitted to the cylinder will be wasted. It is possible, of course, to throttle both the air supply and the gas supply, so as to reduce the total charge while keeping the proportion of the mixture unchanged. It is worth while to do this upon large engines, where economy of operation is a consideration of prime importance; but, in small engines, where simplicity of construction may be more desirable than the highest possible economy, the double-throttling plan is rarely adopted.

Speed-regulating devices that act by cutting off the fuel supply entirely for one or more cycles are called ''hit-or-miss'' governors. In these the engine either receives its full charge and its full explosive impulse, or it does not receive any at all. On the score of economy this method of regulation is quite satisfactory. It permits greater range of speed, however, and hence is objectionable where, as in electric light plants, the utmost steadiness of rotation is of paramount importance.

THE PROBLEM OF STARTING.

One of the problems to be considered in connection with every gas engine is that of starting it up from a state of rest. This may be done by hand, if the engine is small, as is familiarly illustrated in the automobile and the power launch. In larger installations the engine may be set in motion by an electric motor, or by a small, auxiliary gas engine, which, in its turn, is started by hand. Large gas engines are most commonly started, however, by means of compressed air that has been stored in a tank under a pressure of from two hundred to three hundred pounds per square inch, either by the main engine itself, or by a smaller, auxiliary air compressor.

CHAPTER XXXIX.

Gas Producers.

NEED OF CHEAP FUEL GAS.

THE efficiency of the gas engine has led to its increasing introduction into manufacturing plants, and this has called for a careful consideration of the available sources of fuel supply for it. Any sort of fuel—solid, liquid, or gaseous—may be used for operating the steam engine, but the fuel that is introduced into the gas-engine cylinder must of course be gaseous in form. Oil or gasoline may be vaporized and used for this purpose, but no very great portion of our power could be generated in this way, because the available supply of liquid fuel is too limited. Natural gas will serve very well for use in gas engines when it is available, but in most places it cannot be had. True coal gas may also be used, but it is too expensive for use on a large scale. The problem therefore is, to manufacture, in some way, a cheap form of gas that will meet all the requirements of the gas engine, and be available in any part of the country. The gas-producer solves this problem, by generating the desired gas from coal and steam and air.

HOW COAL BURNS.

To understand the operation of the gas producer, a clear idea must be had of the chemical phenomena that occur when coal is burned, both when the air supply is plentiful, and when it is limited. When coal ‘‘burns,’’ it merely combines, rapidly and actively, with the oxygen of the air. For present purposes we may regard the coal as consisting of pure carbon, and consider its combustion as an example of the chemical oxidation of carbon. In reality, coal contains small percentages of sulphur and other substances, but, in studying the action of the gas producer, we may disregard these impurities for the moment. Their influence upon the operation of the producer will be considered in a subsequent paragraph.

TWO KINDS OF OXIDES.

It is a known fact that carbon, when it combines with oxygen, may do so in two different proportions, the product of the combustion being gaseous in either case. Each atom of carbon may take up a single atom of oxygen, being thereby converted into the gas that is known as ‘‘carbon monoxide;’’ or each atom of the carbon may take up two atoms of oxygen, becoming thereby converted into the gas that is known as ‘‘carbon dioxide.’’ (‘‘Monoxide’’ means ‘‘single oxide,’’ and ‘‘dioxide’’ means ‘‘double oxide,’’ these names being adopted for the respective gases under consideration, from the fact that, in one case, the quantity of oxygen that is absorbed is double that which is absorbed in the other.)

FORMATION OF THE DIOXIDE.

When there is plenty of oxygen present, each carbon atom will always take up two atoms of the oxygen. The dioxide is therefore formed whenever the carbon can obtain unlimited quantities of oxygen; and it is to be particularly noted that the dioxide is a perfectly incombustible gas (and therefore useless for operating the gas engine), since in its formation the carbon has already taken up all the oxygen that it can possibly use.

FORMATION OF THE MONOXIDE.

When, on the other hand, the carbon burns under such circumstances that the supply of oxygen is limited, then, although there may be some dioxide formed, there will also be a considerable quantity of the monoxide formed at the same time, simply from the fact that there is not enough oxygen to "go around" and transform all of the carbon into the dioxide. This is illustrated in ordinary coal fires, where the oxygen supply is sufficient to burn part of the coal to the form of the dioxide, but not all of it. The monoxide that is generated often takes fire upon coming in contact with the air above the bed of coal, and burns with the familiar blue flame that is seen in coal stoves and heaters. The blue flame shows that the monoxide is taking up more oxygen, and becoming converted into the dioxide. If we should prevent the monoxide from coming into contact with the air until it had become cool, it would not then take fire, but would remain permanently in the form of monoxide gas, unless we purposely ignited it with a match or an electric spark.

MAKING THE MONOXIDE FROM THE DIOXIDE.

An important fact about these two oxides of carbon is, that if the dioxide gas (with its two atoms of oxygen to every atom of carbon) be passed through a white-hot bed of carbon, the hot carbon of the fire will take one atom of oxygen away from each atom of the carbon in the dioxide gas, thereby reducing this dioxide gas to the form of monoxide. At the same time, the atom of oxygen that is taken from the dioxide combines with some of the carbon in the fuel bed, with the formation of more of the monoxide.

In other words, when an atom of carbon that has no oxygen comes into contact, at a high heat, with another atom of carbon that has *two* atoms of oxygen, the first carbon atom will take one of the oxygen atoms away from the other for its own use, and we shall thereafter have two carbon atoms, each of which is combined with one atom of oxygen. In non-scientific language, this means that when we wish to make carbon monoxide gas, we may do so by passing carbon dioxide through a hot bed of coals. The carbon monoxide gas that is thus formed is combustible, because it has only half the quantity of oxygen with which it is capable of combining. Moreover, in burning and passing again into the form of the dioxide, it gives out a great amount of heat.

AIR GAS.

In the gas producer this process of manufacturing carbon monoxide is carried out on a commercial scale, and the product that is obtained by it, when it is conducted along the lines here indicated, is called ''air-gas,'' since air is the only substance that is used, in addition to the coal. In producers for the manufacture of air-gas, air is passed up through a thick bed of fuel that is very hot throughout. The nitrogen of the air, being chemically inert, takes no active part in the process, but passes on through the bed of coals, and mixes with the carbon monoxide that the producer generates. It merely dilutes the monoxide, and does not in itself serve any purpose, useful or otherwise. The oxygen of the air, however, combines with the fuel with which it first comes in contact, and forms carbon dioxide—there being plenty of air in the lower layers of the fuel, to effect complete combustion. The dioxide so produced passes on through the highly heated coal, which is in a condition to undergo active combustion, if it could only get the necessary oxygen. Nothing reaches it, however, but the dioxide, in which every atom of carbon has already attached to itself two atoms of oxygen. The hot fuel, therefore, takes away half of the oxygen from the dioxide, as has been explained above, and becomes itself partially oxidized into the monoxide, while the dioxide, from which half of the oxygen has been abstracted, is also reduced to monoxide at the same time. The monoxide gas thus produced passes on, without further change, and emerges from the fuel ready for use in the gas engine, save that it first has to be freed from certain accidental impurities that it usually contains.

WATER GAS.

Any kind of fixed, combustible gas that is generated in a gas producer is called "producer gas." The particular kind of producer gas that is technically known as air-gas having been described, it must now be noted that there is another equally important kind, which, from the fact that water and coal are the only materials used in its manufacture, is called "water-gas."

Water is composed of hydrogen gas in combination with oxygen. It is, in fact, simply burned hydrogen. Now white-hot carbon has a greater affinity for oxygen than hydrogen has, and so, if we pass a current of steam through a highly heated bed of coals, the hot carbon will split up the steam, setting free the hydrogen that it contains, and combining with the oxygen to form carbon monoxide, just as in the manufacture of air-gas. The hydrogen that is thus liberated is itself very inflammable, and burns with an exceedingly hot flame. Water-gas, generated as here described, consists chiefly, therefore, of a mixture of hydrogen and carbon monoxide. Unlike air-gas, it contains no nitrogen, or none of any considerable amount, because no air has been blown through the fuel.

ORDINARY PRODUCER GAS.

Ordinary producer gas is a mixture of air and gas and water-gas. In making air-gas the producer can be operated continuously except for such occasional interruptions as may be necessary for cleaning the apparatus, or removing ashes from it, or for performing some other minor operation of like nature. In the manufacture of water-gas, however, the producer cannot be run continuously, because coal cannot be made to burn by merely blowing steam through it. The steam, as it is decomposed, rapidly cools the fuel, and, in order to keep the coals in the requisite state of incandescence, it is therefore necessary to stop the flow of steam every little while, and blow air through the bed of fuel, so that it may become heated up to the required temperature again. Air-gas is formed during this part of the operation, so that, although it is true that pure water-gas contains practically no nitrogen, yet a considerable amount of that gas will nevertheless be found in the actual total product that the producer turns out, this product consisting, as will be seen, of a mixture of air-gas with true water-gas.

THE CONTINUOUS PROCESS.

Hydrogen is a desirable constituent of producer gas, on account of the great heat that it generates when it burns. It is common, therefore, to operate the producer by passing a mixture of air and steam through the ignited bed of coals. In this way a gas is obtained that is rich in hydrogen, while at the same time the process is a continuous one, the air in the mixture that is passed through the fuel being sufficient to maintain an active combustion, while the steam is, at the same time, decomposed with the formation of water-gas. The gas that is generated by this mixed process is what is now usually understood when ‘‘producer gas’’ is mentioned without further qualification.

Although the composition of producer gas varies considerably according to the exact details of the process employed, it will run, on an average, about as follows: Carbon monoxide, 24 per cent; carbon dioxide, 5 per cent; hydrogen, 17 per cent; nitrogen, 54 per cent; of these the monoxide and the hydrogen will burn, while the dioxide and the nitrogen will not, and are therefore without value. A cubic foot of this gas, when burned, gives out enough heat to raise the temperature of a pound of water from 32 degrees Fahr. to about 160 degrees or 180 degrees Fahr.

NATURE OF THE COAL THAT IS USED.

In the practical management of gas producers a great deal of attention is paid to the character of the fuel that is used. Coal screenings, or other finely-divided fuels, are objectionable, because the fuel bed is apt to clog up, and a heavy blast is required to force the air and steam through the mass. On the other hand, the coal fragments must not be too large, or they will expose too small a total surface to the air and steam for obtaining the proper chemical effect, and will also permit too much water-vapor and carbon dioxide to pass through the fuel bed, unaffected. A coal that cokes easily is also objectionable, although it may be necessary to use it in regions where other kinds are too expensive.

''SCRUBBING'' THE GAS.

In explaining the principles of the gas producer it was assumed, above, that the fuel was pure carbon. The coal that is used in actual practice is composed *mainly* of carbon, but it always contains, in addition, substances that affect the output of the producer unfavorably. Before using the gas in the gas engine it is therefore necessary to purify it in some manner, so as to remove the tarry matters, sulphur compounds, ammonia, unconsumed dust, etc., that may be present. Tar, which is particularly objectionable, occurs much more copiously when bituminous coal is used, than when the fuel is anthracite.

These objectionable impurities are usually removed by ''scrubbing'' the gas. Scrubbers, like producers, are made in many forms, but the central idea that they embody is to pass the gas from the producer up through a vertical cylinder that is filled with loosely packed fragments of coke, three to four inches in diameter, while a spray of water is caused to trickle down through the coke. The washing, or ‘‘scrubbing,’’ that the gas receives in this way cleans it very effectively, and renders it fit for immediate use in the engine.

Gas producers may be divided into two main classes, according to the way in which the air and steam are caused to pass through the fuel bed. These classes are technically known as ‘‘pressure producers’’ and ‘‘suction producers,’’ respectively.

PRESSURE PRODUCERS.

In producers of the pressure type, the air and steam are forced through the fuel in the producer by direct pressure. In this type the ash-pit under the fuel bed must be kept tightly closed, to prevent the air and steam from leaving the ash-pit in any direction except upward through the fuel bed. This makes it inconvenient to clean the fires, or to remove the ashes from the ash-pit. Another objection to the pressure producer is, that the quantity of gas that it generates is not automatically adjusted to correspond with the demands of the engine. Hence, in most cases, a gas-holder must be employed in connection with it. Again, carbon monoxide gas is very poisonous, and since any leakage, in a pressure producer, must be *outward,* there is always a possibility of the workmen about the plant becoming asphyxiated. The continued inhalation of even small amounts of carbon monoxide is detrimental to health.

SUCTION PRODUCERS.

In gas producers of the suction type, the air and steam are drawn, or ‘‘sucked,’’ through the fuel bed by the formation of a partial vacuum on the discharge side of the producer. In this case the ash-pit doors may be left open, and no difficulty is experienced in removing ashes. Furthermore, the steam that is used in the process need not be generated under pressure, when the producer is of the suction type. Evidently, too, any leakage that may occur will be *inward,* so that there will be no danger of carbon monoxide poisoning. There was for some time a fear, on the part of gas producer designers, that the inward leakage of air in a suction producer might give rise to dangerously explosive mixtures of air and gas, and that these, upon being fired in some way, might lead to serious consequences. Accidents of this kind have not been realized in practice, however, and they are rather improbable, since the leakage would have to be enormous in amount before it could permit of the entrance of sufficient air to make a true explosion possible.

In theory, the suction producer has the advantage that it may be made to deliver, automatically, the exact quantity of gas that is needed by the engine—the engine, at each stroke, drawing through the producer just the quantity that it needs for the next following explosion. A storage tank would thus be unnecessary, and the operation of the producer would always be regulated directly by the needs of the engine. The suction producer has its weak points, however, and, although it is favored by many, there are many who prefer the other type, in which the air and steam are forced through the fuel bed by pressure.

COMBINATION PRODUCERS.

The so-called ''combination'' producers are really of the suction type, for they are operated by a fan or blower that is placed between the producer and the engine. This draws the air and steam through the fuel bed, by suction, and then passes the gas on, by pressure, towards the engine. Storage tanks are usually employed in connection with combination producers, since the operation of the fan or blower makes storage almost imperative.

The gas producer is already a highly important engineering device, and, without doubt, its importance will increase every year, since the gas engine is steadily replacing the steam engine, even in plants where exceedingly large units of power are employed.

CHAPTER XL.

The Diesel Internal Combustion Engine.

AN ENGINE WITH NEW DEVICES.

THE Diesel Internal Combustion Engine has attracted special attention from mechanical engineers, and hence it may properly receive separate mention in this place. As actually manufactured, it involves a number of mechanical devices that are peculiar to itself, and adapted to its own special requirements. These are well worthy of attention, and yet it is the nature of the heat-cycle that gives the engine its main interest.

Like other internal combustion engines, the Diesel motor is operated by the burning of charges of combustible matter within the cylinder; but the Diesel machine consumes oil fuel instead of gas, the oil being injected into the cylinder in the form of a liquid spray. Kerosene was the fuel first used, but other kinds of oil are now employed also.

THE CYCLE OF THE ENGINE.

The complete cycle of the engine occupies four strokes, or two revolutions. To understand the action that takes place, consider the engine, first, when its cylinder is empty, and the piston is near the back end (or head) of the cylinder. As the piston moves forward on its first stroke, it draws into the cylinder a charge of pure air, unmixed with any combustible. On the return stroke the engine compresses this air into a very small volume, its pressure rising to about five hundred pounds per square inch in the engines of ordinary size, while, at the same time, and in consequence of the compression, the temperature of the air mounts up to a point at which any form of petroleum oil, crude or refined, will take fire spontaneously. At the end of this compression stroke a valve is opened, and a charge of fuel oil is injected into the cylinder, this being drawn from a tank where it is maintained, by cool compressed air, under a pressure of about eight hundred pounds per square inch. Upon entering the cylinder the oil takes fire spontaneously on account of the high temperature, but it does not burn with truly explosive violence, because the injection continues while the engine makes about ten per cent of its next forward stroke. After the piston, urged forward by the gas pressure, has completed the third stroke, the exhaust valve opens, and, on the fourth stroke, the piston sweeps the waste gases out of the cylinder.

A DISTINCTIVE FEATURE.

One of the most distinctive things about the Diesel Motor is the gradual introduction of the fuel oil into the cylinder, this method of feeding being adopted for the purpose of maintaining the temperature as nearly constant as possible, while the heat is being developed in the cylinder, since it is considered that this has certain theoretical advantages on the score of economy.

A MOTOR OF HIGH EFFICIENCY.

The Diesel type of motor is certainly capable of yielding a high efficiency, not only for the reason just given, but also because of the high compression that is realized; and also because the average temperature of the gas in the cylinder, during the generation of the heat, is exceedingly high. A very complete oxidation of the fuel is likewise realized in this motor on account of the considerable excess of air, that is used, —it being possible to employ such excess without loss of efficiency, because the burning of the charge is here more like a true combustion than like an explosion.

It should be noted, also, that no premature explosion is possible in the Diesel Motor, since the cylinder, on the compression stroke, contains nothing but air.

CHAPTER XLI.

The Story of Electricity and Magnetism.

DISCOVERY OF ELECTRICITY.

THE study of electricity dates back many centuries, but all that amounts to much importance, either in theory or in connection with practical applications, has been accomplished within about one hundred and fifty years.

The first fact known concerning electricity was that, when amber is rubbed, it acquires the power of attracting to itself light bodies like bits of straw. Many other substances were subsequently found to share, with amber, this singular property, and, when thus excited, they were said to be ''electrified,'' or ''charged with electricity''—the word electricity being derived from the Greek word ''elektron'' meaning ''amber.''

TWO KINDS OF ELECTRICITY.

In later years, it was found that there are two kinds of electricity. Thus, when glass is rubbed with silk, and sealing wax is rubbed with flannel, each becomes electrified, and each will attract bits of straw. The glass and sealing wax, moreover, will attract each other when thus excited, but it was found that two pieces of electrified glass would repel each other, and that two pieces of the electrified sealing wax would likewise repel each other. The fact that there is a difference between the electricity upon the glass and that upon the sealing wax was expressed by saying that the glass is electrified ''vitreously'' or ''positively,'' and that the wax is electrified ''resinously'' or ''negatively.'' This distinction being recognized, the facts observed in connection with the attraction and repulsion between the electrified glass and wax were expressed in the following statement or ''law'':—''Electric charges of opposite kinds attract each other, while electric charges of the same kind repel each other.''

CONDUCTORS AND NON-CONDUCTORS.

It is impossible to follow all the steps by which our present knowledge of electricity was developed, but a few more of them may be noted. It was found that certain substances, like metal wires, were capable of conveying electric charges to great distances almost instantly, and these were called ''conductors.'' Other substances, like glass and silk, would not convey an electric charge at all, and these were called ''non-conductors'' or ''insulators.''

STATIC FORM OF ELECTRICITY.

It was discovered, furthermore, that when two conductors charged with opposite electricities are brought together, their electric powers not only become greatly reduced, but may even disappear entirely. The opposite electricities neutralize each other, and often with the production of a visible spark. It was also found that an electrically charged body can produce electrical effects in a neighboring conductor without coming in contact with it, or even within sparking distance of it—this phenomenon constituting what is called the ''static induction'' of electricity. In fact, all the phenomena that are observed in connection with bodies electrified by friction are called ''static'' phenomena, to distinguish them from others of a somewhat different apparent nature that we are about to notice; and the electricity that is generated in this way is also called ''static electricity,'' for a like reason.

DISCOVERY OF THE VOLTAIC BATTERY.

A static charge of electricity, as has been noted above, can be sent over a wire—say, from a positively charged body to one negatively charged. The passage of the charge is only momentary in duration, however, and it was reserved for the Italian physicist, Volta, to show, at the beginning of the nineteenth century, how a continuous stream, or current, of electricity could be kept flowing around a wire, by means of that epoch-making invention that is sometimes called, in memory of Volta, the ''voltaic battery,'' and sometimes, in apparently unjust tribute to his great rival Galvani, the ''galvanic battery.''

The electricity that is generated by the voltaic battery is in no wise different from that which is generated by friction, save that one is like a stream of water, and the other is like a mass of water that is stationary and under a high pressure. All the phenomena of static electricity can be observed at the poles of a sufficiently powerful battery or dynamo, and the electric conductors that are in commercial use for transmitting electric power to great distances often carry current electricity at such great pressure that it will jump an inch or two from the wire that conveys it, if another conductor be brought within that distance.

COMPARISON WITH A FORCE PUMP ON A WATER PIPE.

The analogy suggested above between the electric current and a current of water may be usefully extended a little further, in the following manner. The battery may be likened to a force-pump, sending a stream of water through a long pipe which, after a circuitous course, returns again to the pump. The pipe corresponds to the wire that joins the two poles of the battery, and the water corresponds, as before, to the electricity. The battery cannot send out a continuous current of electricity unless the wire, whatever course it may take upon starting out from one pole of the battery, eventually returns to the other pole. Nor can the pump deliver a continuous current of water unless the pipe, after starting out from the high pressure side, eventually returns to the suction side. In other words, the wire and the pipe must each make a complete, closed circuit.

ELECTRIC PRESSURE AND RESISTANCE.

The quantity of the water that the pump can deliver through the pipe in a given time will depend upon the pressure the pump can generate, and also upon the resistance that is offered by the pipe. In like manner, the quantity of electricity that the battery can send around its wire circuit depends upon the electrical pressure, or ''voltage,'' that the battery can produce, and upon the resistance that the wire opposes to the passage of the current of electricity. The resistance of the wire, like that of the pipe, will vary with its length and diameter. The nature of the material of which the wire is composed will also affect the resistance that the electric current experiences, and here the analogy with the water pipe does not apply, because the water goes through the *hole* in the pipe, while the electricity goes through the solid *wire.*

UNITS IN WHICH ELECTRICITY IS MEASURED.

The electrical pressure that a battery can produce is measured in *volts,* the current is measured in *amperes,* and the resistance of the circuit in *ohms*—these names being chosen in honor of three physicists, Volta, Ampere, and Ohm, who did a great deal to increase our knowledge of the phenomena that electric currents exhibit. The units themselves cannot be accurately defined without using rather abstract scientific language that would be out of place here. Roughly, however, it may be said that the volt is about equal to the electrical pressure that is produced by a single cell of gravity battery, and that the ohm is about equal to the resistance, at 68 degrees Fahr., of two hundred and fifty feet of No. 16 copper wire (American wire gauge).

OHM'S LAW.

When we know the electrical pressure (or, as it is technically called, the "electromotive force") that a battery can produce, and also the resistance of a circuit through which it is to deliver a current, we can find out what the current will be, in amperes, by merely dividing the electromotive force of the battery as expressed in volts, by the resistance of the circuit as expressed in ohms. This is the celebrated law of Ohm.

HEATING EFFECTS.

An electrical current always heats the wire along which it is passing, and the quantity of heat so produced may be quite large, if the current is a heavy one.

MECHANICAL AND MAGNETIC EFFECTS OF CURRENTS.

The analogy between the water pipe and the electric circuit fails entirely when we come to look at what happens *outside* of a wire that is carrying an electric current. The current of water in the pipe produces no external effect whatever, but the electrical current in the wire gives rise, in the region outside the wire, to certain effects that are of great importance. For example, two electric currents that are passing along parallel wires repel each other if they are flowing in the same direction, and attract each other if they are flowing in opposite directions. Again, it is found that when a current of electricity is made to flow around a piece of iron but without touching it, the iron is thereby rendered magnetic. If the iron is soft, its magnetism vanishes when the current stops, but if it is a piece of hardened steel, the magnetism it acquires in this way is permanent, and remains after the electric current ceases. (To produce strong magnetic effects, the wire carrying the current should be coiled about the iron many times, the various coils being kept separated by some non-conducting substance, such as cotton.) The fact that an electric current can magnetize iron in this way is of the highest importance in the arts, as many valuable applications of electricity depend upon it.

ELECTRIC INDUCTION.

A current of electricity flowing *steadily* through a wire will not produce any effect upon a closed circuit in its vicinity, provided both the wires are stationary; but whenever the current in the original wire varies in any way, an effect is immediately produced in the neighboring circuit. Thus, when the strength of the current in the original wire increases or decreases, a current appears at once in the other circuit, notwithstanding the fact that the two circuits are entirely separate from each other. A current produced in this way is called an ''induced'' current, and the wire in which it appears is called the ''secondary circuit''—the ''primary circuit'' being the one carrying the current whose changes give rise to the induced current. When the current in the primary circuit is *increasing,* the induced current flows around the secondary circuit in a direction *opposite* to that of the primary current; and when the primary current is *decreasing,* both currents flow in the same direction.

An induced current may be generated in the secondary circuit, even when the primary current is steady, provided either of the circuits is moving. For, if they are being separated from each other, the effect is just the same as though the primary current were decreasing in strength, and, if they are being brought together, the effect is the same as though the primary current were growing stronger.

It is important to understand these general facts about electric induction, because many of the applications of electricity in the arts depend upon them. The dynamo, for example, which is the most important appliance that we have for generating electric currents, is merely a machine for making practical use of the fact that a steady current in a stationary circuit will produce an induced current in a moving circuit.

NATURE OF ELECTRICITY.

The exact nature of electricity is not yet known. As has been pointed out above, it is often useful to regard it as a sort of fluid, flowing through the solid conductors that guide it in its course, and at the same time exerting magnetic and inductive effects throughout the space by which these conductors are surrounded. It is very doubtful if any such fluid really exists, however, and, if it does, it is certainly entirely unlike any other fluid of which we have any knowledge. Many electrical phenomena appear to be due to some kind of a stress or strain or motion in the ether with which science has long taught us that space is filled. Certain authorities have recently thrown doubt upon the very existence of the ether, however, and so the nature of electricity must still be admitted to be an unsolved riddle.

MAGNETISM.—MAGNETS AND THEIR POLES.

It is a familiar fact that hardened steel can acquire the power of attracting other small masses of iron and steel, and a piece of steel that has this property is called a ‘‘magnet.’’ Magnets are often made in the form of straight bars, but, as we commonly see them, they are bent into a shape roughly resembling a horse-shoe, being then called ''horse-shoe magnets.'' If we touch them in their various parts with a bit of iron, we shall find that their attractive power is decidedly greater at or near their ends than it is anywhere else, and at the middle of the magnet the attraction disappears altogether. The ends of the magnet, where the attraction is greatest, are called its ''poles.'' A little further experimenting will show that the magnetism at one of the poles is somehow different from that at the other, for, if we bring two magnets together and find that they attract each other when held in some particular position, we shall notice that they *repel* each other if one of the magnets is then turned completely around, so that its poles become reversed.

TENDENCY TO POINT NORTH AND SOUTH.

If a magnet having the form of a straight bar is balanced upon a pivot, or is floated upon water by the aid of pieces of cork, we shall find that it turns so as to point north and south, or nearly so. It will always be the same pole that is directed towards the north. From this circumstance came the practice of calling one pole of the magnet the ''north pole,'' and the other one the ''south pole''—the north pole of the magnet being the one that always turns towards the north pole of the earth. In the magnets that are sold in the shops, the north pole is usually indicated by a straight mark. A pair of north poles or south poles will *repel* each other; but a north pole will attract a south pole.

THE COMPASS.

The compass, which is used by mariners in navigating the ocean, is merely a light bar-shaped or needle-shaped magnet, mounted on a pivot so that it can turn freely and show which direction is north. In the form of the instrument that is actually employed at sea, a circular card is usually attached to the needle so as to turn with it, and indicate the east, west, and south, as well as the north.

Nobody knows just *why* the compass needle points nearly north and south. Some have maintained that the earth itself is magnetized, and others hold that there are electric currents flowing around the globe, nearly parallel to the equator. Either of these theories would explain all that we know about the behavior of the needle, though the electric current theory looks the more probable.

VARIATION OF THE COMPASS.

The compass does not point *exactly* towards the north pole of the earth, but in the direction of a spot that gradually changes its position (within certain limits), and is now about on the 95th meridian west of Greenwich, and the 70th parallel of north latitude, near the Gulf of Boothia, in British North America. At New York, the compass therefore points a little to the westward of true north, while at San Francisco it points a little to the eastward. The angle between its actual direction and the true north and south line is called the "variation of the compass."

THE LODESTONE.

Although iron and steel exhibit the property of magnetism most markedly, there are many other substances that possess it in a lesser degree. The metal nickel, for example, is attracted by the magnet with quite a noticeable force, though less strongly than iron. Natural magnets, called "lodestones," are also found in nature, and it was in these that the phenomena of magnetism were first studied. They are composed of a certain oxide of iron—the so-called "magnetic oxide." The word "magnet" is derived from "Magnesia," the name of a district of Thessaly from which lodestones were first obtained.

CHAPTER XLII.

Change of Electrical Pressure.

THE INDUCTION COIL.

IT is often desirable, for some special purpose, to increase or diminish the tension (or voltage) of a given electric current. When the given current is intermittent or alternating, it can be transformed so as to have a far higher tension, by means of the induction coil. This consists of a primary coil of relatively coarse wire, wound around a soft iron core, and surrounded by a secondary coil containing thousands of turns of very fine, insulated wire. When a current is started in the interior, or primary, coil, there is a momentary current generated by induction in the outer, or secondary, coil; and, if the number of turns in the two coils are properly chosen, the current in the secondary one may have sufficient pressure (or voltage) to jump for many inches and form a long, lightning-like spark. The current in the secondary is only momentary, however, and it ceases altogether, the instant the current in the primary has become steady. When this state of things is attained, the current in the primary is interrupted, and while it is dying away (which it does in a small fraction of a second) another current, also of momentary duration and of great voltage, is generated in the secondary. But a rapid alternation of the processes here outlined, a correspondingly rapid succession of powerful momentary currents can be made to flow back and forth through the secondary coil.

The secondary current that is produced upon *starting* the primary one flows around the coil in a direction opposite to that in the primary; while the one that is produced upon *stopping* the primary current flows in the *same* direction as the primary one. In most coils the secondary current that is produced by the stoppage of the primary current is far stronger than that which appears when the current in the primary is first established. Hence, although the secondary currents alternate in direction, those in one direction preponderate over the opposite ones so strongly that the secondary coil may be said to have true positive and negative poles.

It must be noted carefully that the induction coil cannot increase the quantity of the electrical energy that is put into the coil in the primary circuit. An induction coil, in fact, may be compared to a lever, which is capable of multiplying a force that is applied to one of its ends, but only by diminishing the amount of the motion to a corresponding extent, at the same time. In fact, the quantity of energy that appears in the secondary circuit of the induction coil must always be materially *less* in amount than that put into the primary circuit of the instrument, because the efficiency of the transformation is not very great. Much of the energy is dissipated as heat, not only in the two circuits, but also in the central soft iron core.

TRANSFORMERS.

In incandescent electric lighting by means of alternating currents, the electricity is sent out from the central station at a very high voltage or pressure, because, when the tension is high, a smaller transmission wire can be used without increasing the loss from the heating of the line wire, and so the initial investment for copper can be materially reduced. The voltage of the current as thus sent out is altogether too high, however, for use in the incandescent lamps, and so a device called a "transformer" is employed for reducing the voltage, at or near the point where the illumination is desired, to a value suited to the lamps that are to be employed.

The transformer is practically the same in principle as the induction coil, but its primary and secondary circuits are wound somewhat differently, since the transformer, unlike the induction coil, is designed to change a high-voltage current, of no very great quantity, into a low tension one of greater volume. The primary coil of the transformer forms a part of the circuit through which the current in the main line passes, and the secondary coil, which is electrically separate from the primary one, carries the incandescent lamps that are to be supplied. Transformers are occasionally employed, like induction coils, to *increase* the voltage of the current. They are then technically known as ''step-up'' transformers, the usual kind being called, for the sake of distinction, ''step-down'' ones.

MOTOR GENERATORS.

A transformer, it should be noted, is used only in connection with alternating currents. It would not operate upon a line carrying a continuous, steady current, since there is no inductive effect in it except when the primary current is changing—either increasing or decreasing.

When it is desired to change the voltage of a *continuous* current, or to transform an alternating current into a continuous one, a device called a ''motor-generator'' is employed. This, as its name indicates, is merely a combined motor and generator, built as one machine,—the current in the main line operating the motor, while the motor, in its turn, drives the attached dynamo. As the dynamo of the motor-generator can be designed in any way we please, it is evident that any sort of a current desired can be realized in this way. The only limiting condition is, that the total quantity of electrical energy that the motor-generator gives out cannot exceed that which is put into it.

CHAPTER XLIII.

Measuring Electricity.

THE GALVANOMETER.

ELECTRIC currents are measured in "amperes." To perform the measurement in the case of any given current, we may make use of any of the various effects that the current can produce, and the measurement will then consist in comparing the magnitude of the particular effect we have chosen, with the magnitude it has when produced under like conditions by a current of one ampere. The galvanometer which is most often used in making such comparisons, depends for its action upon the fact that a coil of wire carrying an electric current produces magnetic effects in the space surrounding the coil. These magnetic effects are stronger, the stronger the current, and they may be compared by seeing how great a deflection they produce in a compass needle that is poised near the coil (often in its exact center). To be able to measure a current in amperes by this method, it is necessary to find out, first, how much the given needle is deflected when a current of one ampere passes through the given coil. For this purpose the galvanometer is tried, at the outset, in a circuit that is carrying a current of known strength; and after the deflection for one ampere has been ascertained in this way, the instrument is ready for use in measuring any unknown current that is within its capacity.

For many purposes it is quite sufficient to have an exceedingly delicate galvanometer, which does not *measure* the current that passes, but which indicates its existence even though it be extremely small. Such a galvanometer may be constructed by making the compass needle very light and suspending it by a single silk fiber. Its delicacy may be still further increased by attaching a small, light mirror to the magnetic needle, and letting the mirror reflect a beam of light upon a distant screen. The slightest movement of the needle and mirror will then be made visible by the motion of the reflected spot of light.

MEASUREMENT BY CHEMICAL MEANS.

In accurate scientific work, electric currents are often measured by passing them through a carefully prepared chemical solution of silver, and finding out how much silver they can deposit from it, in a given time, upon a polished silver plate. The weight of silver that a current of one ampere will deposit in one minute, is accurately known, and so it is easy to calculate the strength of the current that was passing through the given solution when our experiment was made, as soon as we have found out the weight of the silver it has deposited in a given number of minutes.

AMMETERS AND VOLTMETERS.

In the arts, galvanometers that are constructed so as to show how many amperes of current are passing through a given circuit are called "ammeters" (that is, ampere-meters). By a slight modification, a galvanometer can be made to indicate the number of volts of electro-motive force that there are between the two points to which its terminal wires are attached, and, when so designed, the instrument is called a "voltmeter."

MEASURING ELECTRICAL RESISTANCE.

The electrical resistance of a piece of wire can be measured with great accuracy by means of the device called, from the name of its inventor, "Wheatstone's bridge." This consists of four resistances, which are located in pairs on the two arms of a branched circuit.

The two branches of the circuit are "bridged," or connected, by a cross-wire that passes around a delicate galvanometer, each end of this cross-wire being in contact with the corresponding branch of the circuit at some point *between* the two resistances that the branch includes. Three of the four resistances used must be known while the fourth is the one to be measured. One of the known resistances is varied until the galvanometer indicates that no current is passing in the cross-wire. It can be shown that a certain simple proportion must hold true among the four resistances when this is the case, and, by the aid of this proportion, the unknown resistance is easily calculated. Other methods of measuring electrical resistances are also used but the "bridge" method (or some modification of it) is by far the most accurate.

HOW ELECTRICITY IS PRODUCED.

Long before current electricity was known, machines were in use for generating static electricity by friction, and these are still employed, to some extent, for certain medical purposes, and for exciting the vacuum tubes that are used in the production of X-rays. In the earlier forms of static machines, a large circular disk of glass was made to revolve in such a way as to be rubbed by silk or some other equivalent substance, the electricity that was generated being collected from the glass by a series of metal points and delivered to a big main conductor. In later machines the rubber is dispensed with altogether, and the electricity is generated by static induction; these "influence machines," as they are called, are quite ingenious, and hard to understand without some study. Static machines do not work well unless they are operated in very dry air. It is therefore usual to enclose them in glass cases, the air within which is kept dry by chemical means.

THE VOLTAIC OR GALVANIC BATTERY.

As has been previously noted, the voltaic (or galvanic) battery, discovered by the Italian physicist Volta, was the earliest known device for the production of a continuous current of electricity. We have a number of other practical methods at the present time but the voltaic battery is still widely used, although it has been greatly improved since it was first discovered. In its best form, Volta's original battery consisted of a series of cups, each containing a plate of zinc and a plate of copper (or of silver), these being immersed in a solution of common salt. The metal plates of such a battery are called its ''electrodes,'' and the ends of these plates, projecting above the water, are called its ''poles''—the copper (or silver) plate being known as the ''positive'' electrode, or pole, and the zinc one as the ''negative'' electrode. In setting up the battery the positive pole of one cell is connected by a wire to the negative pole of the next one, and so on throughout the series, so that when the connections are completed as indicated, we simply have one unconnected copper plate at one end of the battery and one unconnected zinc plate at the other end, to serve, respectively, as the positive and negative poles of the battery as a whole. When these two poles are joined by a wire, a current of electricity is found to flow between them, along the wire, the zinc plate being meanwhile slowly oxidized and dissolved in the salt solution. It is usual to say that the current flows through the wire from the positive pole to the negative one, but this is a mere matter of convention because we really know nothing at all about the direction in which the current actually does pass.

The galvanic batteries of the present day are based upon the same general principle as Volta's. That is they all consist of two electrodes immersed in liquid, or in a moist medium of some kind that takes the place of the liquid. One of the electrodes is almost invariably made of zinc, the other being made either of copper or of carbon—the energy that is used up in generating the electric current being derived from the oxidation of the zinc, while the carbon (or copper) remains unaffected.

POLARIZATION.

A battery like Volta's is quite active for a short time, but, as the electric current continues to flow through it, the substances (such as zinc oxide and hydrogen gas) that are formed in consequence of the chemical activity within the cell, begin to accumulate upon or near the electrodes, and these interfere greatly with the operation of the element, so that presently its yield of electricity is very materially cut down. The battery is then said to be ''polarized'' and it will not work properly again until these products have been removed in some way. Modern batteries contain chemicals that combine with the waste products which are naturally produced in the cell, these being called ''depolarizers,'' since they destroy the substances that produce the polarization.

THE DANIELL BATTERY.

Three general types of battery are now employed, in which the removal or destruction of the polarizing matter is effected by such chemical means, many others being also known, though they are not in general use. Of the three to which we refer, the Daniell battery and its modifications are perhaps the most interesting, since in them the problem of depolarization is solved with ideal completeness. In its original form the Daniell cell consists of an external glass vessel, within which is a porous cup of unglazed earthenware. The porous cup is filled with a saturated solution of sulphate of copper, and contains a copper electrode. while the space outside of the cup is filled with weak sulphuric acid, and contains an electrode of zinc. In the operation of this battery the zinc is gradually eaten away by the sulphuric acid, passing into solution in the form of zinc sulphate; and at the same time the solution of sulphate of copper is also gradually decomposed with the deposition of metallic copper upon the copper electrode. The porous cup merely serves to prevent the solutions from mixing.

GRAVITY BATTERY.

The Daniell battery is still used, though a somewhat different form has been given to it. The porous cup is now dispensed with, and the solutions are kept separate by the fact that one of them is heavier than the other—from which circumstance the modified form is called the "gravity battery." The copper plate is placed in the bottom of the containing jar, and the zinc plate is suspended at the top of the jar, in a horizontal position. The lower part of the jar contains a saturated solution of sulphate of copper, while the upper part is filled with a weak solution of sulphate of zinc, which floats upon the copper solution by reason of its relative lightness. As the copper sulphate solution is strongly blue, the composition of the liquid in the cell can be seen at a glance by noting how far up the blue color extends.

The gravity form of the Daniell cell is excellent in cases in which the battery is likely either to be used steadily for a considerable time, or to lie idle for quite a period. It does not polarize, and there is but little chemical action within it when the electric current is not flowing. It must be kept motionless when it has once been set up, because agitation will cause the two solutions to mix. Gravity batteries were formerly in very general use for telegraphic purposes, but at the present time the current used in telegraphy is largely generated by low-tension dynamos.

BICHROMATE BATTERIES.

Another common and highly useful type of battery is that in which the depolarizing is effected by the substance known to chemists as bichromate of potassium. In this case the battery consists of a plate of zinc and one of carbon, immersed in a solution composed of bichromate of potassium and weak sulphuric acid. A battery so constituted is very powerful and may be used with success for operating small electric motors and other apparatus in which a strong current is required for a short time. Chemical action goes on in the bichromate cell to some extent, even when the current is not passing, and hence it is usual to lift the zinc plates out of the solution when the battery is not in action.

SAL AMMONIAC BATTERIES.

For light work of an intermittent character, such as the ringing of bells and the operation of telephones, the various forms of battery of which the Leclanché was the original type are highly useful. These may be allowed to stand idle for months without any serious chemical action taking place in them, unless the current is passing. They also have a good electromotive force, but they can be used at their full power for only a few minutes at a time, because they polarize somewhat rapidly, and must then be allowed to stand until they recover. A cell of this kind consists of a plate of carbon and a rod of zinc, immersed in a solution of sal ammoniac. The carbon is also surrounded by a depolarizing mixture composed of black oxide of manganese and other substances, the various forms of this battery differing from one another almost solely in the composition of this mixture, and in the way in which it is disposed in the battery. In some forms the depolarizing substance is mixed with pulverized carbon and the whole is pressed into the form of a flat or cylindrical plate, which serves as the electrode.

DRY BATTERIES.

So-called ''dry batteries'' are dry only in the sense that they contain no free liquid that could run out, if the cell were turned bottom side upward. They are really modified forms of the sal ammoniac cells just described, the liquid being replaced by a moist paste containing sal ammoniac and some depolarizing mixture.

THE DYNAMO.

Although the primary battery, as just described, will always be useful for the generating of electricity in small quantities, it is to the dynamo that we must look when we wish to produce electricity on a large scale, for use in the arts. Neither the battery nor the dynamo can do more than transform other kinds of energy into the electrical form, however—the voltaic battery developing electricity at the expense of chemical energy, while the dynamo develops it at the expense of mechanical energy.

The dynamo (or ''generator,'' as it is often called) is a practical and highly important application of the principle of electric induction in moving circuits, and consists essentially of a big magnet (called the ''field magnet''), with an armature revolving between its poles, and driven by some mechanical power or other. The armature consists of a mass of soft iron, around which are wound a considerable number of turns of copper wire, covered with an insulating substance such as cotton. The soft iron tends to concentrate the magnetic force of the field magnet, so as to make as much of it as possible pass through the loops of the wire with which the armature is wound.

The fact that a current of electricity is produced when a closed circuit is moved in a magnetic field, has already been explained in an earlier paragraph, and in the dynamo this fact is put to practical use. As the wire upon the armature revolves, an induced current of electricity is generated within it, and this is drawn off at the end of the moving armature by means of a device called a ''commutator.'' In small dynamos, or generators, the field magnets are often made of steel, permanently magnetized; but in the larger ones the field magnets are always made of soft iron, and are kept magnetized by surrounding them with coils of wire through which part or all of the current of the dynamo itself passes. In some dynamos the whole current that is generated in the armature is sent around the field magnets, these being called ''series machines.'' In others, called ''shunt machines,'' only a portion of the current is so used. Each of these methods of exciting the field magnets has its advantages and disadvantages, and one or the other is adopted, in practical work, according to the circumstances under which the machine is to be used.

DIRECT AND ALTERNATING CURRENTS.

Some dynamos deliver a current that always flows through the main circuit in the same direction, these being called ''direct current'' machines. Some, on the other hand, deliver a current that flows sometimes one way and sometimes the other, the reversals of direction usually taking place many times a second. Such generators are called ''alternating current'' machines.

The direct (or continuous) current is essential in electroplating and in electrolysis generally. It is also the most convenient form to use in running electric motors, although, if the motors are situated at considerable distances from the generator that feeds them, the alternating current is preferable, because it can be transmitted more economically over long distances. For a similar reason the alternating current is largely employed for incandescent electric lighting, when the lamps are more or less distant from the central station supplying the electricity.

DIRECT-CONNECTED MACHINES.

Dynamos are operated by steam power, by water power, or by gas engines, and it is important that their speed should be exceedingly uniform, since any marked unsteadiness in this respect gives rise to annoying variations in the current. They are often driven by belts, but at the present day there is a strong preference for what are known as "direct-connected" units. These consist of a steam engine or gas engine, built together with a generator in such a way that the two form a single machine. The dynamo being then directly upon the same shaft with the engine, such loss of efficiency as the use of a belt may involve is saved. Steam turbines are used in many plants for operating electric generators, and the turbine, since it normally runs at a high speed, may easily be operated in direct connection with the dynamo. Enormous quantities of electricity are now generated by water power at Niagara Falls and elsewhere, and the tendency toward the utilization of our water powers in this way is becoming more and more marked each year.

ELECTRICITY DIRECT FROM COAL.

The problem of transforming heat energy into electrical energy without the intervention of cumbersome apparatus like the steam boiler, steam engine, and dynamo, is a fascinating one, and many inventors have tried their hands at it. Batteries have been devised in which carbon is consumed instead of zinc, and other plans have been tried, too numerous to mention. Most of the would-be discoverers and inventors who have worked upon this problem have overlooked the fact that there is a theoretical limit to the possible efficiency of an apparatus of this kind, when the transformation is attempted under given conditions, and that no apparatus, of whatever nature it may be, can possibly have an efficiency greater than this limit. An inventor who desires to engage in the search for such a method of generating electricity should therefore first inform himself thoroughly respecting the teachings of the mechanical theory of heat, because, by so doing, he will save himself much useless labor that would otherwise be expended in striving to accomplish the impossible.

THERMO-ELECTRICITY.

One of the most interesting directions in which the search for simpler methods of generating electricity from heat has been carried out lies in the field of thermo-electricity. A circuit composed of one kind of metal does not manifest electrical phenomena unless a battery is associated with it, or induction effects are produced in it from outside causes. But if part of the circuit is composed of one metal (say copper), and part of another (say iron), then a current of electricity will appear in it when the junctions where the two metals come together are kept at different temperatures. The electricity so produced is in no wise different from that obtained in other ways, but it is called ''thermo-electricity,'' to signalize its mode of production. Heat is absorbed at the hotter junction and given out at the colder one, and, when the current is passing, some heat is also absorbed and emitted in other parts of the circuit. On the whole, the quantity of heat absorbed is greater than that given out, and it is the excess of the absorbed heat over that emitted that is converted into electrical energy. Many attempts have been made to devise a form of thermo-electric apparatus which will apply this principle for the economical generation of electricity in quantity, but no great measure of success has yet been attained.

One difficulty is that the voltage obtained is quite low, so that a large number of thermo-electric elements must be arranged in a chain or series, in order to get a current great enough for any practical application. An even more serious difficulty is, that the efficiency of the thermopile (as this apparatus is called) appears to be necessarily small, so that it looks hopeless to give the device any form in which a satisfactorily large proportion of the available heat shall be transformed into electrical energy.

CHAPTER XLIV.

The Transmission of Power by Electricity.

INDIVIDUAL MOTORS IN FACTORIES.

THANKS to the perfection that dynamos and electric motors have attained, electricity is now widely used for the practical transmission of mechanical power, and such power is delivered in vast amount over distances ranging from a hundred feet or so up to many miles.

In factories it is by no means uncommon for each machine to be fitted with a separate electric motor, these motors being operated by electric currents furnished by dynamos located in the engine room. In this way it is possible to avoid the frictional losses that are inseparable from the use of shafting and belts. Moreover, it is usually necessary to run shafting at all times, while the electric motors, on the contrary, are operating only while the machines which they drive are at work.

REASONS FOR TRANSMITTING POWER.

It is often profitable to transmit power, electrically, to great distances. For example, a large waterfall may be available as a source of power, and yet it may not be convenient or expedient to use the power at the fall itself. Water wheels and dynamos are therefore installed at the fall, and the electricity generated is distributed by wire to the points at which the power is to be used. Again, it is cheaper to generate steam or gas power on a large scale than upon a smaller one. Large steam plants and gas engines are more efficient than small ones, the coal and other supplies being purchased at greater advantage in large quantities, and the cost of labor, per horse power, being also less. It may well prove to be cheaper, therefore, to generate power on a grand scale, and distribute it electrically to small consumers, than it would be for each of the small consumers to maintain his own independent power plant. In many cases, too, it would be impractical to have a steam engine or a gas engine for the direct generation of the desired power; and even where it would be possible and economical, to employ such engines, the convenience to the small power user of having a motor that he can operate at any time without trouble, is great enough to be worth serious consideration for its own sake.

The engineering problems that are involved in electric power transmission have all been pretty well worked out, and, in connection with the installation of any proposed system, the questions to be considered are now mainly those relating to expediency and economy.

IMPORTANCE OF THE LINE WIRES.

The efficiencies of modern dynamos and motors are excellent, and hence in the installation of a proposed long-distance transmission line, in which it has been concluded that the probable expense of the total plant, including interest on the investment, is justified by the results that may reasonably be expected, the problems that have to be most carefully considered are those that relate to the line wires that carry the current. These have to be properly insulated, of course, to avoid waste of the current through leakage, but there are also other problems of serious moment connected with them.

LOSS OF HEAT FROM THE LINE WIRES.

As has been stated in an earlier paragraph, an electric current always heats the conductor over which it passes. The heat so generated is proportional to the resistance of the line wire, and to the *square* of the current; and it constitutes a serious source of loss, because it does not serve any useful end, but it merely radiated into the air and lost. A given amount of power can be transmitted either by sending a large current at a low pressure, or by sending a smaller current at a higher pressure; and since the energy that is wasted upon any given line by the heating of the wire depends solely upon the current, and not at all upon the electrical pressure (or potential), it is advisable to keep the current as small as practicable, by running the plant at as high a pressure as is consistent with proper insulation, and with the proper operation of the transformers and motors at the receiving end of the line.

CHOOSING THE SIZE OF THE LINE WIRES.

When the size of the current that is to be transmitted has been determined, we may make the resistance of the line wire (and therefore the waste of energy in the form of heat) as small as we please, by making the wire correspondingly large. The line will always have *some* resistance, however, and therefore there will always be *some* heat-loss. It can be shown that, as far as pure theory is concerned, the most economical size of wire to use for the conductors is that for which the annual loss, due to the generation of heat in the line, is just equal to the annual interest upon the capital expended in buying the wire. In practice this equality is approximated, but certain other considerations come in to modify it to some extent.

In transmitting power over short distances the direct current is usually employed; but when these distances are measured in miles, it is far more economical to use the alternating current.

CHAPTER XLV.

Chemical Applications of Electricity—Electrolysis.

DAVY'S EXPERIMENTS.

ALMOST as soon as the voltaic battery was invented, it was noticed that the electric current was capable of performing chemical work, and Sir Humphrey Davy, at the beginning of the nineteenth century, succeeded by its means in decomposing potash and soda (which had previously been supposed to be simple bodies, incapable of decomposition), and obtained from them the metals now respectively known as potassium and sodium.

DESCRIPTION OF THE APPARATUS.

The action of electricity in decomposing substances, or in building them up, by its direct action (as distinguished from such action as may be due to heat) is called "electrolysis." In order to use the current for such purposes the substance upon which it is to act must be in the fluid state, that is, it must either be dissolved in some liquid, or it must be heated to such a temperature that it melts itself. The details of the arrangement of the apparatus that is used may vary, but in the typical case two plates of metal or carbon are immersed in the liquid on opposite sides of the tank or containing-vessel, the electricity entering the liquid through one of these, and leaving it through the other. The plate (or electrode) at which the current enters is called the "anode," and the one by which it leaves is called the "cathode."

ELECTROLYTES AND NON-ELECTROLYTES.

It is only certain classes of substances (called ''electrolytes'') that are decomposed by the electric current. Thus a solution of common salt is decomposed, but a solution of sugar is unaffected. When the current is passed through a solution capable of acting as an electrolyte, chemical action begins at once, and the amount of chemical decomposition that is produced is exactly proportional to the intensity of the electric current that is passing, and to the time during which it continues to pass.

ACTION IS CONFINED TO THE ELECTRODES.

It is important to note that no evidence of chemical action can be detected anywhere in the solution, except in the immediate vicinity of the electrode plates. The effects are not increased by separating the electrodes further, so that the current will traverse more of the solution; but on the contrary, any change that such a separation may produce will be in the direction of a *diminution* of the action, on account of the increased resistance due to the greated amount of liquid interposed in the circuit.

PRIMARY AND SECONDARY PRODUCTS.

Whatever chemical products may be formed by the current will appear at the electrodes themselves. The actual first products of the decomposition are called the ''primary'' products, and these may or may not be actually obtained, according to the way in which the experiment is carried out. They may combine, for example, with the fluid electrolyte with which they at once come in contact, as they are formed, and, when they do so, they give rise to what are known as ''secondary'' or ''end-products.'' It is evident, therefore, that the actual phenomena occurring in electrolysis may sometimes be exceedingly complicated. In working out a practical plan for applying electrolysis to some definite commercial end, the electrical engineer has to develop a plan for making the process yield just what he wants, whether this be a primary or a secondary product.

ELECTROPLATING.

Electroplating is one of the simplest forms of electrolytic work. To carry it out, the anode is made of a plate of the metal that is to be deposited, and the articles that are to be plated serve as the cathode, the liquid in the tank being a solution of some salt of the metal that is to be deposited. When the current passes, the dissolved metallic salt in the solution is gradually decomposed, the liberated metal being deposited upon the articles to be plated; and at the same time an equal amount of metal dissolves from the anode, and passes into the solution, which is thereby kept at constant strength.

PURIFICATION OF COPPER.

Electrolysis is now extensively used for purifying certain of the metals. Nearly all of the pure copper of commerce, for example, is prepared in this way. The process consists simply in passing the electric current through a copper solution containing a cathode of pure copper and an anode of the copper that is to be refined. It is found that, by properly regulating the current and observing certain other details, nothing but pure copper will be plated upon the cathode, and nothing but pure copper will go into solution at the anode; the impurities that are liberated at the anode, as this dissolves away, sinking to the bottom of the tank as a sort of sludge or mud, which often contains enough gold or silver to go a long way towards paying for the entire operation.

MANUFACTURE OF SODIUM, MAGNESIUM AND ALUMINUM.

Electrolysis is used not only for purifying metals, but also, in certain cases, for obtaining them from their compounds, in the metallic form. Practically all of the sodium, magnesium, and aluminum, for example, that are used in the arts are prepared in this way.

Sodium is manufactured by passing the electric current through melted caustic soda. Magnesium is similarly prepared from melted carnallite, which is a double chloride of magnesium and potassium. Aluminum is manufactured by the electrolysis of purified aluminum oxide, dissolved in a fused bath composed of the mixed fluorides of aluminum and sodium.

MANUFACTURE OF CHEMICAL COMPOUNDS.

Many attempts have been made to apply electrolytic principles to the manufacture of chemical compounds, as well as to the isolation of metals and other elements. These have met with a certain amount of success, although much remains to be done in the future. Barium compounds have been prepared on a commercial scale, at a cost said to be materially less than would be necessary by the older methods. Certain compounds that are ordinarily classed as of organic origin can also be prepared by electrolysis. Of these iodoform, vanillin, and certain derivatives of aniline and naphthalene may be specially mentioned. The possibilities of chemical electrolysis are so great, and the rewards of success so large, that American manufacturers are investing immense sums in apparatus to make chlorine and soda, one plant at Niagara Falls using upwards of 6,000 horse-power. The reactions that would naturally be expected from simple theoretical considerations are seldom those that actually occur, however, and, while the application of electrolysis to organic synthesis is full of promise, comparatively little has yet been accomplished in the way of realizing its possibilities in a commercial way.

CHAPTER XLVI.

The Electric Furnace.

PRINCIPLE OF THE FURNACE.

THE electric furnace is a device for obtaining exceedingly high temperatures by means of a current of electricity, and it depends for its operation upon the fact that an electric current always heats a conductor through which it is passing. If the conductor offers but little resistance, and the current is also small, there is but little heat produced; but when a heavy current is sent through a high resistance, the quantity of heat generated may be exceedingly great.

HOUSEHOLD HEATERS.

If the temperature that is to be produced is not very high, the electric current may be sent through a coil of wire having a considerable resistance, the wire being thereby warmed and becoming capable of serving as a source of heat of moderate intensity. The electric heaters that are used to warm the air in trolley cars are made on this principle, and so also are those that are used in the household, for heating irons, broiling meats, etc.

THE TRUE ELECTRIC FURNACE.

In the arts, however, it is desirable for many purposes, to make use of temperatures higher than the melting points of any of the conducting substances from which heating coils can be made, and hence, in such cases (which are nearly always those contemplated when the electric furnace is mentioned), it becomes necessary to generate the heat in some other way. For producing these high temperatures, the electric current is therefore caused to pass across a gap between two carbon electrodes (just as in the case of the electric arc lamp), or else it is caused to flow through a loosely packed mass of poorly conducting material. In either case the resistance is high, and, by forcing a large current through it, a great quantity of heat is generated.

TEMPERATURE OF THE ELECTRIC FURNACE.

The main advantage of the electric furnace lies in the fact that by its use we can realize a heat far more intense than can be attained by any other means. Temperatures greater than 3,600° Fahr. cannot be had by burning carbon or hydrogen in pure oxygen, for at or below this point combustion ceases. An electric current flowing in an arc across a gap of high resistance will continue to generate heat, however, so long as the apparatus holds together; and there is no theoretical limit to the temperature that can be attained in this way, if the heat that is generated is not permitted to escape. There is such a limit in practice, however, not only because the unavoidable losses of heat from conduction and radiation become heavy, but also because the furnace tends to destroy itself by its own action. Temperatures as high as 6,000° Fahr. can be obtained, however, and at this point platinum, lime, magnesia, carbon, quartz, and other similarly refractory substances actually boil and pass away in vapor.

CHEMICAL USES.

Certain of the metals which can be obtained from their oxides only with difficulty by other means, may be prepared readily in the electric furnace; and many compounds which cannot be formed at all at lower temperatures are easily obtained by the action of its enormously higher heat. Thus carbon unites with lime in the electric furnace to form calcium carbide, which is now familiarly used for the generation of acetylene gas, and silica unites with carbon to form carbide of silicon, which is the exceedingly hard substance that is known commercially as ''carborundum,'' and used as an abrasive for grinding and polishing purposes.

MANUFACTURE OF GEMS.

Several kinds of gems have been prepared artificially by melting the proper metallic oxides in the electric furnace, and allowing them to crystallize in solidifying. Artificial rubies, made either in this way or by fusing smaller natural stones together, are hard to detect, save by gem experts. Many attempts have been made to manufacture diamonds in the electric furnace, by crystallizing carbon. When carbon solidifies from the melted state, however, it passes into the form of graphite; and although Moissan has actually manufactured diamonds by cooling the carbon under enormous pressure, the crystals that he obtained were exceedingly minute, and the cost of manufacturing them was many times greater than that of natural diamonds of the same size.

CHAPTER XLVII.

The Electric Motor.

EARLY MOTORS.

THE electric motor is a machine for the conversion of electrical energy which has been supplied from an external source into mechanical energy. Such machines were made before the dynamo was invented. The early machines were exceedingly wasteful of energy, however, as the conditions for the efficient conversion of electrical energy into mechanical energy were not then understood.

Moreover, the electricity was then of necessity furnished by voltaic batteries, and hence was expensive to produce, metallic zinc being too costly a material to consume in the place of fuel. On the whole, therefore, the early motors were little more than philosophical toys, and they were never employed for the generating of mechanical power for useful purposes. After the invention of the dynamo, and the consequent cheapening of electricity, greater attention was directed to the electric motor, and now it is one of the most efficient machines that we have.

DYNAMOS AND MOTORS COMPARED.

In the dynamo a circuit is forced, by mechanical power, to move in a magnetic field, and electric currents are thereby produced in the moving circuit. In the electric motor, on the other hand, an electric current is sent through a movable circuit placed in a magnetic field, and the mechanical attractive or repulsive action of the magnetism upon the electric current causes the circuit to be moved in the field. In a sense, therefore, the motor is exactly the converse of the dynamo, the motor generating mechanical power at the expense of electric energy, while the dynamo generates electric energy at the expense of mechanical power. In many cases the design of the two is very similar, save for such external and non-essential variations of form as may be required to adapt the motor to the special work that it is to do. The motor may be exposed to severe conditions, for example, and it may be handled by men who know but little of electric principles. In such cases it must be built with reference to liability of derangement.

KINDS OF MOTORS.

Motors are classified as "direct-current," "alternating-current," and "polyphase," according to the nature of the currents by which they are operated.

The "induction" motor may also be separately mentioned, although its distinguishing feature is not so much the character of the current that operates it (which must be alternating), as it is the way in which the mechanical effect is produced.

The direct-current motor is the simplest in form, and the easiest to understand. As its name indicates, it is intended to operate upon a line carrying a continuous current. It is, in effect, a direct-current dynamo, which is caused to revolve backward by sending through it a current of electricity more powerful than the motor itself could generate, when running as a dynamo at the same speed. Unlike certain of the forms of alternating-current motors, the direct-current type is self-starting, and will begin to revolve as soon as the current is turned on.

SERIES AND SHUNT MOTORS.

Direct-current motors may be further classified as (1) series machines, (2) shunt machines, and (3) compound, or shunt-and-series machines. In the series motor the armature and the coils of the field magnet are connected "in series," or so that the entire current that enters the motor passes first through one of them, and then through the other. In the shunt motor, on the other hand, the current that enters the motor is caused to divide into two parts, one of these parts passing through the armature coils, while the other goes through the coils of the field magnet.

There is little or no choice between the series motor and the shunt motor so far as efficiency is concerned, but each possesses certain characteristics of its own, so that one is the better form to use under one set of conditions, and the other is the better under other conditions. The series machine, for example, is preferable when the speed of the motor has to vary within wide limits in its service, and also where frequent stoppages are necessary, and where a strong turning effort is required, in starting up. It is therefore adopted on trolley cars and elevators, and in other places where the conditions mentioned have to be met. The speed of the series motor varies widely as the load changes, and with the load thrown off entirely the motor will race, and may attain a speed sufficient to damage itself.

The shunt motor, when supplied with a current of constant electromotive force (or potential-difference), runs at a fairly uniform speed, no matter what the load upon it may be, provided it is within the range for which the machine is designed. Hence the shunt motor is widely used when a comparatively uniform speed is required.

The shunt-and-series motor embraces the principles of both the shunt and the series types. It may be described as a shunt machine whose field magnet is provided with a certain number of additional (and separate) coils, carrying the same current that flows through the armature. By the use of this compound winding the motor can be made to run at a speed still more uniform than that attainable in the simple shunt motor.

ALTERNATING CURRENT MOTORS.

Alternating-current motors, which (as the name implies) are operated upon circuits carrying alternating currents, are less easy to understand than direct-current motors, and they can here be hardly more than mentioned. They are efficient and satisfactory in most respects, and their adoption is almost imperative when the mechanical power is to be developed at any considerable distance from the dynamo that generates the electricity, because the transmission of a direct current having an electromotive force adapted to motors of reasonable design would be wasteful if the distance were great. Certain forms of alternate current motors will not start of themselves, but must be brought up to speed by some other agency before they will work properly. Other forms will start alone, but are not capable of overcoming any considerable mechanical resistance until they are revolving rapidly, so that with these the load must not be thrown on until the speed has been brought up to the normal value without it. Still other forms are made that will start readily under full load.

POLYPHASE MOTORS.

The most interesting motors, perhaps, are those that operate on ''polyphase'' currents, but they involve principles that are too intricate to be more than roughly outlined here. In an alternating current dynamo of the simplest type, the electric current that is delivered by the dynamo increases from nothing up to a certain maximum value, then dies away again and is subsequently reversed in direction, after which it increases to a maximum in the new direction, and then once more dies away to nothing. This entire cycle is completed in a mere fraction of a second, and it is repeated over and over again, as long as the dynamo runs. The current-flow, it will be seen, is somewhat analogous to the ebb and flow of a tide-wave, and hence it is customary to speak of it as consisting of ''electric waves'' in the circuit. In the simplest form of the alternating current dynamo there is only one main circuit, and there is only one series of electric waves sent out by the machine over this circuit. In polyphase motor work there are two or more entirely distinct circuits, involving four or more separate conductors (though in special cases which cannot here be considered, certain of these conductors may be dispensed with). The dynamo sending out the current, has two or more separate sets of armature coils, so that it gives two or more simultaneous alternating currents, each like the simple one just described, and each going forward over its own separate circuit. The electric waves that are sent out over the several circuits are identically alike, except that they are not in the same "phase;"—that is, one set is ahead of the other by a quarter of a wave-length if there are two sets of generating coils on the dynamo, or by some other fraction of a wave length if there are more than two such sets of coils. If there are two sets of waves over two circuits, the system is said to be a "two-phase" one; if there are three sets, it is said to be a "three-phase" one; and, in general, any system in which there are several sets of such waves, over as many different circuits, is said to be a "polyphase" system. In spite of the added complication of polyphase machinery, it has certain marked advantages which have caused its use to become widely extended. Polyphase motors are self-starting, for example, and the attendant who has them in charge does not need to understand their construction, nor the principle upon which they act.

INDUCTION MOTORS.

In the "induction motor" the armature, or moving part of the machine, forms a complete electric system in itself, so far as concerns any actual connection with the outside or external circuit, or with the field magnets. Such motors therefore do not have commutators. They can be used upon circuits carrying a simple, single-phase alternating current, although in this case they have to be started by some external agency. The induction motor is mainly used upon two-phase or three-phase circuits, however, and under these conditions it is self-starting, and gives a strong turning effort from the very outset. The changing currents in the field magnet coils *induce* currents in the armature coils, and these are acted upon, in turn, by the field coils so as to make the motor revolve.

CHAPTER XLVIII.

The Storage Battery,

IT DOES NOT STORE ELECTRICITY.

THE storage battery (also known as the "secondary battery" or "accumulator") is an apparatus which is often referred to as "storing up" electricity, for use at some future time, as compressed air would be stored in a tank. It does not really store *electricity*, however, but it is so constructed that, by passing a continuous electric current through it for a time from a dynamo certain chemical changes are produced, which render it capable of subsequently generating electricity like any other battery—its yield of current continuing until the chemical changes produced by the charging current from the dynamo have disappeared.

EFFICIENCY.

The quantity of electrical energy that can be drawn off from a good, modern storage battery that is properly used, may be as great as 85 or 90 per cent. of that which is expended in preparing it for use, or "charging" it.

USES OF THE STORAGE BATTERY.

The storage battery is of great value in electric light and power stations, where it serves to supplement the dynamos that are used to generate the current that the station gives out. It may be charged during the hours when the demand for current is relatively light, and may be drawn upon when the demand for current is again heavy. Storage batteries are also used for the propulsion of electric motor carriages, and they have been tried with varying success upon trolley cars, although they are hardly beyond the experimental stage in this latter service. Small installations of storage cells are useful for many minor purposes, such as for running small motors and for operating the electric igniters of engines using gas and gasoline as fuel.

The *positive* pole of a storage battery is the one at which the current *leaves* the cell when the battery is *discharging* itself.

THE LEAD CELL.

Nearly all of the successful storage batteries consist of lead plates immersed in weak sulphuric acid, the surfaces of the plates being prepared in some way to enable them to retain the products of decomposition that are formed in the battery by the charging current.

THE TWO MAIN TYPES.

In lead cells of the Planté type the plates are "formed" (that is, made ready for service) by receiving a coating of spongy metallic lead, so that they can absorb and retain considerable quantities of gas. In the earlier batteries of this type the sponginess was produced by electrical means, after the battery was set up; but, as the process employed for this purpose was slow and expensive, it is now usual to coat the plates with spongy lead in some manner, before the parts of the battery are assembled.

In lead cells of the Faure type the plates are coated in advance with a sort of paste the essential constituent of which is some oxide of lead. The paste upon the negative plates becomes reduced to spongy lead the first time the battery is charged. The Planté and Faure cells differ mainly, therefore, in the method of manufacture.

In the more recent cells of either of these types the plates are usually formed into grids, or lattice work, or provided with perforations of other shapes, the active material (whether it be paste or spongy metallic lead) being held in the interstices.

WHAT HAPPENS IN CHARGING THE BATTERY.

When a storage cell is being charged, the electric current from the dynamo decomposes a part of the water with which the sulphuric acid in the cell is diluted, the hydrogen resulting from the decomposition passing to the negative lead plate, and the oxygen to the positive one. If the cell is of the Planté type, the hydrogen is merely absorbed by the pores of the spongy surface, and is retained there, mechanically, in unchanged form. If the cell is of the Faure type, the first part of the hydrogen that is generated in the *first charging* of the battery reduces the oxide of the paste upon the negative plate to the spongy metallic form. When this reduction is complete, the rest of the hydrogen that is generated in the first charging (and practically *all* of that which is generated in subsequent chargings) is absorbed and retained by the spongy lead, just as in the Planté cell.

The oxygen, which goes to the positive plate, combines with the spongy lead that is there, in the Planté cell, and forms an oxide of lead, which becomes partially transformed into sulphate by the sulphuric acid in the liquid of the cell. What happens to the oxygen in the first charge of the Faure cell depends upon the composition of the paste that is used in its construction. When the battery has once been brought into its permanent operating condition, however, the chemical processes involved in charging and discharging are practically the same, whichever the type. In charging, hydrogen gas is stored in the pores of the negative plate, while the oxygen resulting from the decomposition of the water combines with the lead of the positive plate, and with some of the sulphuric acid of the liquid, to form a deposit, upon this plate, composed of a mixture of sulphate and oxide of lead.

DISCHARGING THE BATTERY.

In discharging the cell, the hydrogen lodged in the negative plate re-combines with the oxygen that is stored in the oxide and sulphate upon the positive plate, and the cell can continue to generate its current until this re-combination is complete.

CARE IN THE USE OF THE STORAGE BATTERY.

The extent to which the charging operation should be carried must be learned by experience. If it is pushed too far, the sponginess of the positive plate will be increased, and, in some forms of cell, continued over-charging may destroy this plate entirely by causing it to crumble to fragments. The proper limit of the charge may be judged by the appearance of the plate, by the amount of free gas given off from the cell in bubbles, by the specific gravity of the solution in the cell, and by the slight variation that occurs in the electromotive force of the cell.

When the charging is completed, the cell is ready for use. It has an electromotive force ranging from about two and one-half volts to a little under two volts, and its internal resistance is exceedingly small. In using a storage battery as a source of electricity, the current should never be continued until the battery has exhausted itself, because this tends to damage the plates. At least 25 or 30 per cent. of the original charge should still remain in storage when the recharging is again begun.

THE EDISON BATTERY.

The Edison storage battery, which is still in the experimental stage, is not of the lead-sulphuric-acid type. The plates of this cell are stamped out of thin sheet steel, and are then nickel plated. They contain shallow pockets in which is packed the active material that takes the place of the lead oxide paste in the Faure cell. In the Edison cell the pockets of the positive plate are filled with peroxide of nickel, and those of the negative one with finely divided iron. The liquid of the cell is a solution of caustic potash, and, since this will absorb carbonic acid from the atmosphere and be thereby converted into the carbonate, the cell must be sealed up, or otherwise protected from the air.

Part V.

Means of Transportation and Communication.

CHAPTER XLIX.

The Mail Coach.

THE STORY OF TRAVELING IN EARLY DAYS.

IT seems queer to think that until about eighty years ago railroads did not exist, and that when they were first built they were even thought impossible. In 1827 the *Boston Courier* said that a railroad from Boston to Albany would be as useless as a route from Boston to the moon. But some two centuries before that, the coach was just as heartily abused for blocking the street. The first coach in England was built for the Earl of Rutland in 1555, and a little later the same maker built one for Queen Elizabeth. Before that, people went on horseback, on foot, or in a sort of sedan-chair or litter.

The early coaches must have been anything but agreeable to ride in, for even as late as 1747 a coach had no windows, and no seats or railing on top; whoever sat on the top held on as best he could. In 1761 there were only thirty-eight people in Philadelphia who had any sort of carriage; there were three coaches only. And there were no such things as mail coaches or stages; people who travelled did so in their own carriages, or on their own horses, or walked.

It was, in fact, impossible to have anything like a regular stage line until proper roads were built. Even in Europe the only roads in good condition were the old Roman roads, and as late as 1720 there was not a carriage in Scotland. The first English mail coach ran between Bristol and London in 1784. If this was the state of things in long-settled England, it may be imagined that the roads in this country were hardly more than the old Indian trails through the woods. We had too many other things to do for the first hundred and fifty years to take time for roadmaking.

The kind of road we call macadamized is named after John MacAdam, who went from this country to London in 1783, and began building roads there of small stones and gravel. Roads of this kind were built through Massachusetts and Pennsylvania as soon as in England, and with them the stage-coach days began.

THE PRAIRIE SCHOONER OF THE EARLY SETTLERS.

The first stages were ''Conestoga wagons,'' afterward called ''prairie schooners,'' long covered wagons with three or four backless seats, drawn by six or eight horses. The only baggage allowed was what could be put under the seat or carried in the lap. In 1795 Parker's Mail Stage between Whitestown and Canajoharie charged fourpence a mile, and carried fourteen pounds of baggage without extra charge; one hundred and fifty pounds had to be paid for as if it were another passenger. In 1797 the stage to Albany left New York every day at ten o'clock, and reached Albany at nine o'clock of the morning of the fourth day, and the fare was $7. Stages to Vermont ran three times a week. Often passengers who started from town in a fairly comfortable stage would find, after travelling a day, that the journey must be finished in a rough farm wagon hired by the manager of the stage-line to carry passengers the rest of the way.

The great test of speed was the delivery of the

ROME IN THE DAYS OF AUGUSTUS.—A scene on the Appian Way, when the imperial city was at the height of its glory and splendor.

President's message, and the mail coach driver who could do that quickest got the contract for carrying the mails, which meant a large sum of money for those days. It took ten days for the news of the death of Washington to reach Boston. Mails were carried by the coaches as far as they went, and the rest of the way on horseback. It was common for ladies, or timid travellers, to ride with the postman when they made a journey, thus securing safety, and being sure not to lose their way.

INTERESTING RULES OF STAGE COACH DAYS.

In 1818 coaches began to be built in the egg-shaped form we all know, and swung on straps which were called "thoroughbraces." It was not uncommon for one of these straps to be worn out, and break, when the road was very bad, and then the jolting inside may be imagined. There was a small rack for trunks behind, and a perch for the driver, with a footboard, in front. These old coaches, while more comfortable than the wagon, were still clumsy. When Spanish princes were entertained by Talleyrand at Valencay, while they were the prisoners of Napoleon, they came in a state coach belonging to the court of Spain. When they went away, all arrangements were made for them to go in that same state coach; it was brought out of the castle stables, all the ceremonies of leave-taking were finished, the princes got in—and then it was found that the coach was so heavy it could not be got to the road! Washington Irving, when a young man, was one of a pleasure party in a coach which stuck in the mire not far from New York, and after the men in the party had vainly attempted to pry it out of the mud-hole, it had to be left there while the party went on foot to the nearest tavern. An old story of the early coaching days is of a coach in which first, second and third class fares were charged, but the seats all seemed alike. When the first bad spot in the road was reached the driver got down, opened the door of the coach, and called out:

"First class passengers, keep your seats. Second class passengers, get out and walk. Third class passengers, get out and push!"

THE STAGE COACH WAS PICTURESQUE.

With the building of the "Concord coach," however, the glory of the mail coach began. The first was built at Concord, N. H., in 1827, and the old stage-coach used by Buffalo Bill in his show is the sort of vehicle it was. These coaches usually carried fourteen passengers when filled; nine sat on the three seats inside, two with the driver, and three on the top on a seat behind the driver. Sometimes there were places for only six inside, three riding backward, and in the more modern coaches, intended for mountain travel, there are more seats on top, where people like to sit to enjoy the view. The usual speed on a good road was ten miles an hour, but Dan Gordon, a famous stage driver of the old times, carried the President's message thirty-two miles in two hours and twenty minutes, changing teams three times. In 1832 there were one hundred and six coach lines starting from Boston, and the *Boston Traveller* was started as a stage-coach paper.

These stages usually started very early in the morning; three o'clock was the usual time, and sometimes the traveller was called at half past two; a stop was made for breakfast two or three hours later, so that one travelled the first few miles in total darkness without seeing who else was in the coach. There used to be a story in the old school readers of a man who travelled all night with a bear, thinking him a man in a fur coat! The stage stopped at places along the road for meals, and again for the night, at about ten o'clock. A journey of several days by stage was a wearisome thing.

IN STAGE-COACH DAYS.—A Spanish diligence. This exciting method of transportation may be experienced to-day by travelers who will seek the remoter parts of Spain.

The driver of the stage was sometimes expressman and postman as well. He always drove four horses and sometimes six. The four-horse team was driven with four reins; that for the near wheel horse went under the little finger of the left hand; for the leader, from the next finger; for the off wheel horse, under the third finger of the right hand, and for the leader, from the first finger; the whip, which was about five feet from butt to holder and twelve feet from holder to end of lash, was carried in the right hand, pointing to the left toward the ground. There was not much highway robbery in this country in the old coaching days in the East, because Americans early began to carry their money in checks and drafts instead of in gold. In the West, where the express companies carried a great deal of gold, a stage-driver had to know how to handle a gun as well as the reins. Stage-driving was a hard business. The drivers usually did not have even beds at the tavern, but slept rolled up in a blanket or in their buffalo coats, around the fire in the kitchen. In one old Massachusetts tavern one may still see holes cut in the wall at one corner, by which the teamsters could climb up to their room in the second story without coming through the house or wakening the tavern-keeper. Yet most of the old stage-drivers loved their business, and were never contented in any other. The very last of the old type of city stages were those seen only a few years ago in Fifth Avenue in New York, and there were men among the drivers who had been driving omnibuses for forty years. But just as the mail-coach became really comfortable to travel in, railroads came in, and drove the stages out of business on all the principal roads. This was about 1836. Since then, stage-lines run only where the railroads do not.

CHAPTER L.

The Steam Engine and The Locomotive.

HOW THE STEAM ENGINE WORKS.

THE steam engine is a machine in which mechanical power is developed by the pressure of steam against a round, disk-shaped piston that moves back and forth in a cylinder, which it is made to fit as perfectly as possible. As the piston travels to and fro, its motion is transferred, by means of a pair of jointed rods, to a crank that is attached to the shaft of the engine; and in this way the shaft is made to revolve continuously in one direction.

After having pushed the piston the entire length of the cylinder, the steam that has done the work is allowed to escape, and a fresh supply is made to enter the cylinder on the other side of the piston, so as to force it back again to the end of the cylinder where it was at first; and these processes follow each other regularly, over and over again, as long as the engine runs.

THE PRINCIPLE OF EXPANSION.

In the earliest engines, steam was admitted to the cylinder at full boiler pressure throughout the entire length of each stroke; but James Watt showed that it is far more economical to cut off the supply after the piston has traveled only part way down the cylinder, letting the steam that has been admitted *expand* as it pushes the piston the rest of the way. Watt's principle was adopted at once, and is used in all modern engines.

THE LAZY BUT RESOURCEFUL VALVE-BOY.

The steam engine was originally a very crude machine. It moved slowly, and it is said that the valves

WATT DISCOVERING THE POWER OF STEAM.—His mother is scolding him for wasting time that should have been given to his books.

regulating the entrance and escape of the steam were operated by hand. There is a legend (though perhaps it is not true) of a lazy but clever boy named Humphrey Potter, who was once employed to operate the valves of such an engine, and who found the job monotonous and uninteresting. He therefore rigged up some cords and other devices, so as to make the engine open and close its own valves, and having done this he probably left the engine room by the back door, confident that it (and his own pay) would go on as well as ever, without his personal attention. Something happened to the rigging that he had devised, and the engine stopped. His apparatus and his absence was then discovered, and the legend says that the use of automatic gear for operating the valves of steam engines dates from this time. Let us hope that the boy was properly rewarded, and not discharged for neglect of duty.

THE SLIDE VALVE.

At the present day the admission of steam to the engine, and its removal after it has done its work, is effected, in small engines, by causing a piece of metal to slide back and forth over openings that lead into the cylinder, so as to close them at times, and at other times to leave them open. Engines of this sort are called ''slide-valve'' engines. They are simple in construction, although they do not permit the principle of expansion, advocated by Watt, to be applied as fully as might be desired.

CORLISS ENGINES.

When the highest degree of economy is demanded, a different kind of valve motion is used, by which the admission and exhaust of the steam can be regulated with great nicety. The valve motion that is most widely favored for this purpose was originally invented by George H. Corliss, an American inventor, about 1849, and all engines in which his principle is adopted are called "Corliss" engines, though it is common to prefix to this title the name of the actual builder. The multitude of engines with names such as "Smith-Corliss," "Jones-Corliss," "Robinson-Corliss," and so on, has led to the entire class being facetiously called "hyphen-Corliss" engines.

STEADYING ACTION OF THE FLYWHEEL.

One of the most conspicuous things about a steam engine, as we look at it superficially, is the big wheel which is fixed upon the main shaft and called the "flywheel." The belt that takes the power from the engine usually runs over this wheel, but the flywheel has another highly important use, in addition to carrying the driving belt. The steam pressure on the piston, acting first in one direction and then in the other, exerts an intermittent action upon the shaft, the turning effort that it produces being great when the crank is nearly at right angles to the piston rod, and next to nothing at the instants when the crank and the piston rod are nearly in a straight line with each other (that is, when the engine is passing what are called its two "dead centers"). Hence the motion tends to be jerky, and in engines that are heavily overloaded this action can sometimes be distinctly perceived by the eye. The flywheel is intended to render the motion of the engine smoother and more uniform, and if it is big enough and heavy enough it will steady the engine so that the irregularities to which we have referred will be greatly reduced, and the motion of the shaft and of the machinery that the engine drives rendered nearly uniform.

FLYWHEEL EXPLOSIONS.

The strains that are produced by centrifugal action in the big wheels that are whirled around at high speed by our modern engines are often enormous, and for this reason the wheels must be made very strong. Sometimes, in spite of the care that is taken in designing and building them, they fly to pieces, and carry death and destruction wherever their fragments strike. There are about sixty-five or seventy accidents of this kind in the United States each year.

THE GOVERNOR.

The flywheel, by its momentum, equalizes the motion of the engine so far as it is affected by variations of power in different parts of a revolution, but it cannot guard against gradual change of speed, and hence some other regulating device must be provided for that purpose. If the engine generates less power than the belt is taking away, it tends to slow down, and if, on on the other hand, it generates more power, then the excess must be expended in making the flywheel turn faster. To guard against variations of this kind, the engine is always provided with a regulating apparatus known as the ''governor.'' On slow speed engines the governor usually consists of a pair of balls that are connected to the main shaft by a belt, or by gearing, so that they revolve with a speed that varies with that of the engine. When the engine runs too fast, the increased centrifugal force of the balls causes them to fly farther apart, and in doing so they operate a mechanism that cuts off the supply of steam; and when it runs too slow the centrifugal force of the balls diminishes and they drop down and come nearer together, thereby permitting more steam to enter the cylinder. The governor therefore automatically regulates the supply of steam, so that the quantity delivered to the engine is always just right for the amount of work that it is doing.

In high speed engines the governor acts upon the same general principle, though it is then usually built in an entirely different form, and placed inside of the flywheel.

THE ‘‘SAFETY STOP.’’

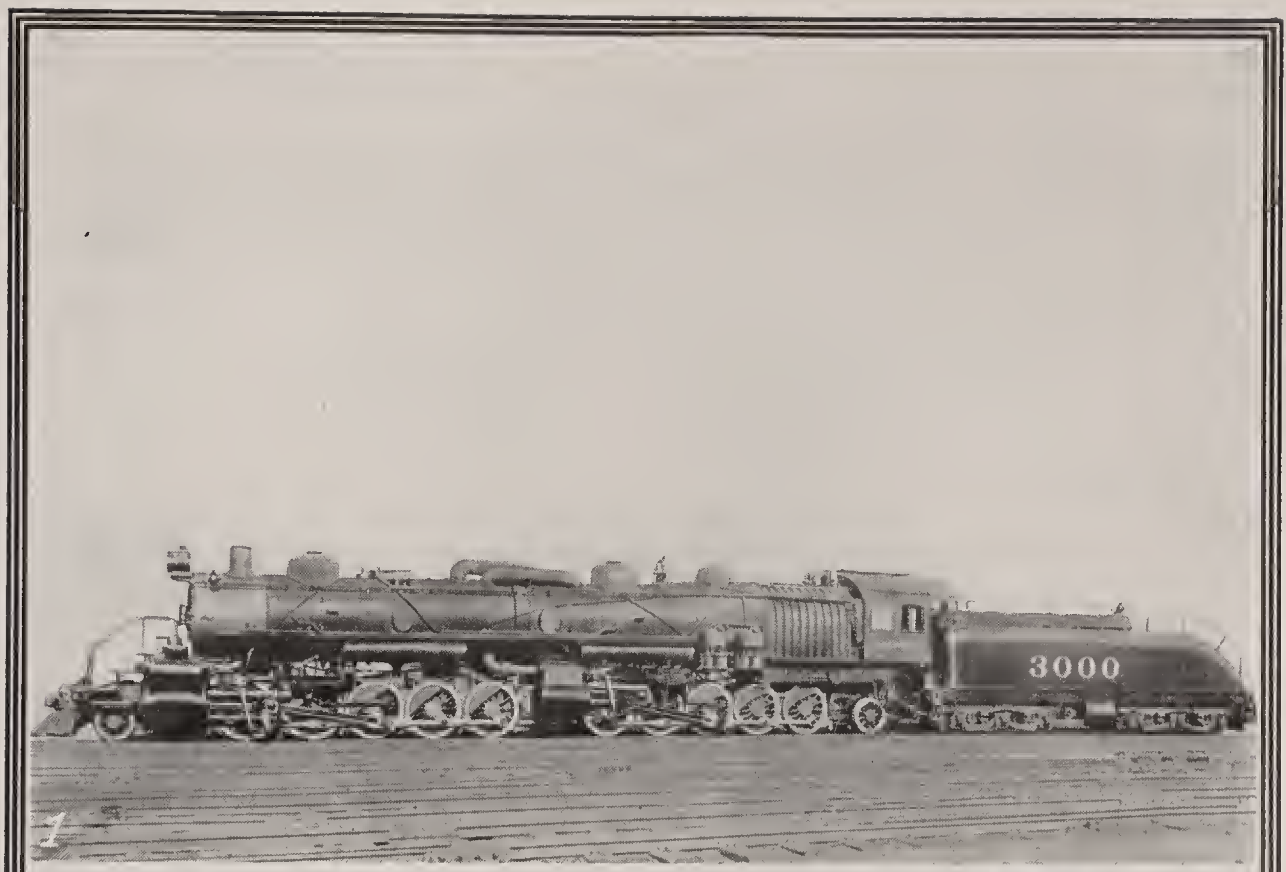
In good modern practice there is a marked tendency toward providing each engine with what is called an ‘‘engine stop,’’ or ‘‘safety stop.’’ This is a device, entirely separate from the ordinary governor, and in addition to it, for cutting off the steam supply entirely, if the speed at any time should exceed the greatest value that can occur in the normal operation of the engine, and while it is still well within the limit at which the stresses in the whirling flywheel become dangerous and threaten the destruction of the wheel.

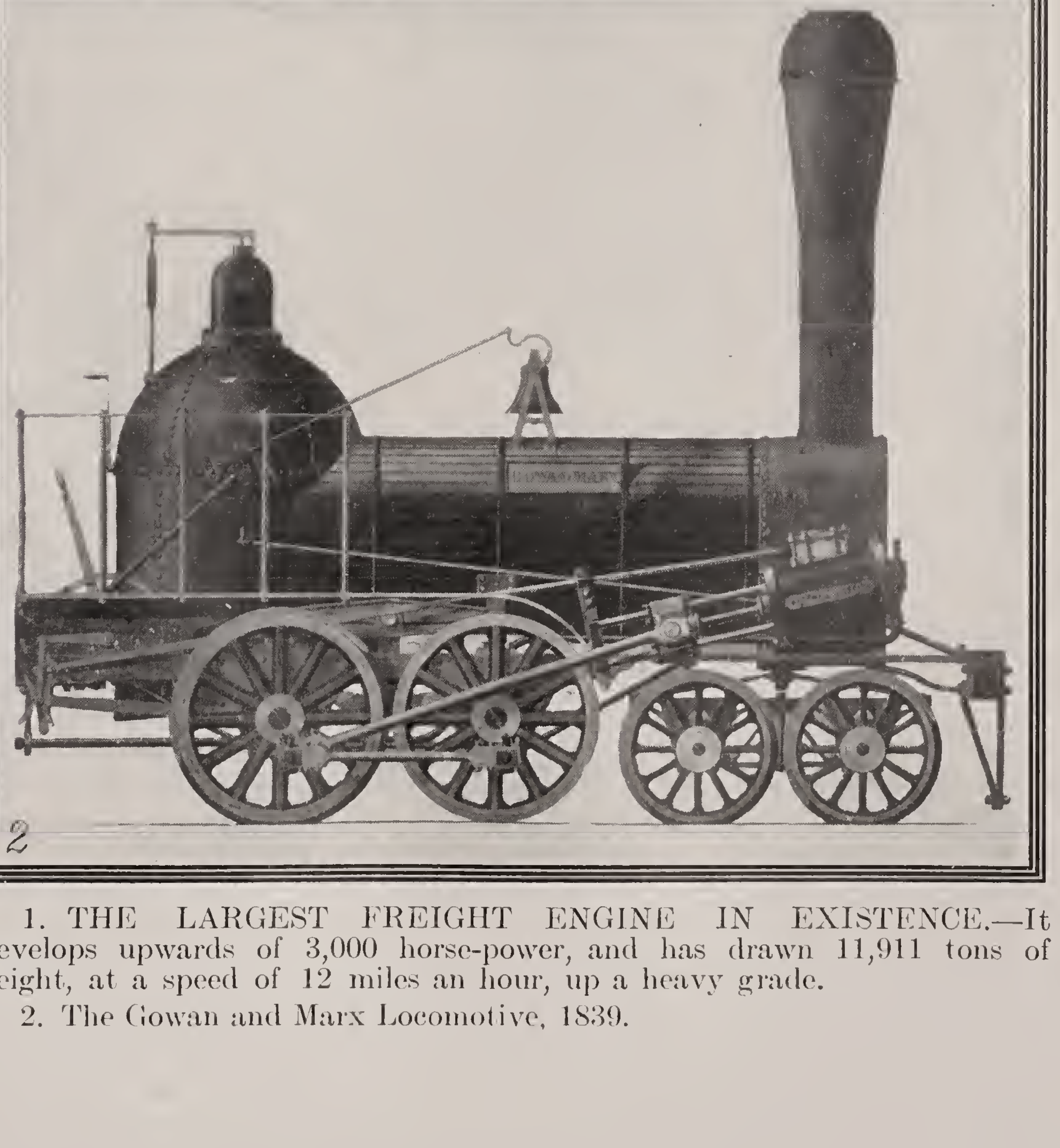
CONDENSING ENGINES.

Many engines are provided with what are called ‘‘condensers,’’ these being closed vessels which receive the exhaust steam from the engine, and condense it to the form of water. The condenser is kept cold by means of a current of water flowing around it, or pumped into it in the form of a jet or spray, and the steam, as it comes out of the engine, is condensed immediately, so that there is always a very good vacuum in the vessel. This helps the engine, and adds to its power, because (to express the fact in a popular, even if slightly incorrect way) the vacuum ‘‘sucks’’ on one side of the piston, while the steam from the boiler is pushing on the other side. When efficiency of operation is the primary consideration, engines are usually run on the condensing principle; but many of them, for one reason or another, are also run without condensers.

COMPOUND, TRIPLE, AND QUADRUPLE ENGINES.

As economy is found to depend in large measure upon the extent to which the steam is expanded, and as there is a limit beyond which it is not practicable to expand it in any one cylinder, many engines are built with two cylinders, to allow the expansion to take place in two stages. Such engines are called ‘‘com-





1. THE LARGEST FREIGHT ENGINE IN EXISTENCE.—It develops upwards of 3,000 horse-power, and has drawn 11,911 tons of freight, at a speed of 12 miles an hour, up a heavy grade.

2. The Gowan and Marx Locomotive, 1839.

pound.'' In them the steam from the boilers first enters a relatively small cylinder, where it is expanded to a certain amount, and then, instead of being passed directly into the air or into the condenser, it is transferred to another cylinder, larger than the first, where it is expanded still further.

In recent years it has become common to expand the steam successively, in this way, through three or even four cylinders. Such engines are called ''triple expansion'' and ''quadruple expansion,'' respectively. They are used mainly in marine practice, though they have also been employed upon land to a limited extent.

POWER FROM A POUND OF COAL.

The amount of heat energy that a pound of coal gives out in burning is surprisingly large. If we could obtain all of it, in practice, in the form of actual mechanical work, one pound of pure coal, free from ash or clinker, would give us a power equal to that of a strong horse, acting continuously for five hours. But there is a theoretical limit to the fraction of this power that an actual steam engine can generate—a limit which applies, no matter how perfect the engine may be—and there must always be, in addition, a considerable loss due to the imperfection of the engine and to that of the boilers. From these two causes together, it results that in our very best engines, when running in connection with the most efficient boilers, one pound of pure coal will afford a full horse power for only about one hour. Yet if we take a pound of coal in our hands, and look at it, this yield appears astonishingly large.

ROTARY ENGINES.

Many inventors have turned their attention to the designing of rotary engines, in which the power is not to be developed by first driving a piston to and fro and then changing the motion to a circular one, but so as to produce a uniform rotary motion at the very outset. Now there is no doubt a field for a good rotary engine, and yet the inventors who have worked over the problem have been prompted to their task, for the most part, by an incorrect conception that is doomed to disappointment from the very outset. They have had the idea, namely, that since there are two points in every revolution of the ordinary steam engine at which the power of the piston is not exerted advantageously—the points, namely, at which the crank of the engine is on the "dead centers," or in line with the engine shaft and the piston rod—there must necessarily be a considerable loss of power which could be saved if the "dead centers" could be avoided. Students of mechanics know that this idea is erroneous, and that the loss that the most of the advocates of the rotary engine assume to exist, really does not exist at all.

IS ANY OTHER LIQUID BETTER THAN WATER?

Another thing that inventors have very generally tried to exploit is the notion that the vapor of some liquid other than water might be used for running the engine, with distinct advantage. All the available liquids that have looked promising have been tried in this way, but without success. The search is an inviting one, at first glance, because it takes so much heat to merely *evaporate* the water and get it into the form of steam, before it can be used at all. It seems as though some other liquid might be found that could be vaporized much more easily, with the result that more of the heat that is furnished by the fuel could be effectively employed in expanding the vapor and doing the actual work of the engine. This hope, alluring as it is at first thought, is nevertheless illusory, because the theory of heat shows that a necessary relation exists between the heat required to vaporize a liquid, and the work that the vapor of this same liquid can do in subsequently expanding; and this relation is found to be of such a nature that it makes exactly no difference at all what liquid is used, so far as theoretical considerations are concerned, and so long as the engine works between the same limits of temperature.

THE LOCOMOTIVE AS A STEAM AUTOMOBILE.

The locomotive is a sort of steam automobile, consisting of a steam engine and a boiler, mounted upon wheels, and arranged so that the entire power generated by the engine is spent in impelling the whole machine forward.

The difference in appearance between the locomotives in the United States and in European countries is very marked, though not so much so, now, as it was twenty years ago. This is due, in considerable measure, to the fact that in this country the cylinders of the engines are placed far apart, so that the cranks through which the power is transmitted to the driving wheels are *outside* the wheels; whereas in European designs the cylinders are placed closer together and more nearly under the boiler, and the cranks are forged upon the shafts, and located *inside* the driving wheels.

FREIGHT AND PASSENGER LOCOMOTIVES.

In all countries the driving wheels of locomotives that are used to draw fast passenger trains are very large, while those of the locomotives used for hauling freight are much smaller. This is because speed is the most important element in the passenger locomotive, while in the freight locomotive the most important thing is the ability to haul heavy loads. A locomotive goes forward a much greater distance with every revotion of the engine when it has big driving wheels than it does when it has smaller ones; but with the smaller wheels the engine can exert a much greater leverage, and hence can draw a heavier load, though necessarily at a reduced speed.

It has been found to be more economical to run long and heavy freight trains, than it is to handle the same amount of freight matter upon a number of shorter ones; and this fact has led to the construction of freight locomotives of tremendous size and power. The largest one in existence at the present time is the huge ''Mallet'' freight locomotive of the Atchison, Topeka & Santa Fe railroad.

TAKING WATER WHILE RUNNING.

On many lines provision is made for the locomotives of fast express trains to take water without stopping. For this purpose a long shallow iron pan is placed in the middle of the track at some level spot, and this is kept filled with water. As the locomotive approaches it the engineer lowers a sort of scoop, which dips below the water and gathers it up in large quantities as the locomotive speeds along. Coal cannot be taken on in the same way, but that is less important, because the weight of water consumed in a trip is several times as great as the weight of the coal that is burned.

QUALIFICATIONS OF AN ENGINEER.

To make an ideal engineer for a fast passenger locomotive, a man would have to be almost more than human. First of all, he must understand his machine thoroughly, and know its every mood and motion. He must have a good eye for color, because the color of a light at night means everything to him and his precious human freight. One man in seven is at least slightly defective in this respect, and it happens that red, so widely used as a danger signal because it is so conspicuous to the normal eye, is the very color to which the defective eye is least sensitive. Uncertainty as to red would render an otherwise excellent engineer entirely unfit for running a locomotive where human lives or large amounts of property were at stake, and candidates for such positions are therefore carefully examined on this point before they are given important runs.

Above all, the engineer must be quick to see and to act. He must have a cool head, and be free from any likelihood of fright or panic, even when unexpectedly confronted by instant and mortal peril. Without the least hesitation he must do the thing that makes for the safety of his train, even at the cost of his own. life.

CHAPTER LI.

Railroads: Their Service and Great Influence.

THE OLD-FASHIONED COACH ON RAILS.

WHEN the early man went in pursuit of game or an enemy, his only means of locomotion was his two sturdy legs; then, as game became shyer or more nimble, or an enemy pursued faster than was safe or pleasant, he leaped on the back of an animal, finding this mode of travel easier and more rapid. As it became necessary to transport commodities as well as persons, and as growing luxury demanded an easier seat than the back of a moving animal, the whole class of carriages, carts, coaches and wagons came into use, and when the world reached the point of substituting steam-power for horse-power —when steam, or some other motive power, *had* to come just when it did, since thirty thousand mail horses were being killed off annually in England alone —what more natural than that the first "car" should be the old fashioned coach, taken up bodily and put upon rails?

The story of the beginning of the railroad and the prejudices that had to be overcome, is one of the most interesting in the whole history of race progress, as it is one of the most important. It is by contrasting that transition period with the present—which is, right under our eyes, only a transition from steam to electricity—that one can get a faint idea of the grandeur of a thought which has welded nations, and accelerated the on-push of civilization.

FIRE FROM THE SUN STARTED IT.

It was, of course, the discovery of the principle of the steam engine by James Watt in 1773, that started it all; and it was the trip of George Stephenson's Rocket at Rainhill, England, in October, 1829, that clinched it. But as early as 1804, Richard Trevithick, a Cornish inventor, applied steam power to the drawing of loads. It was to the engineer of this noisy contrivance that peasants would kneel down and implore: "My de-dear Mr. Devil, do drive on and away as fast as ever you can!" In this same year Oliver Evans in Philadelphia was operating a steam wagon, or "boat-on-wheels," as it was called. It was in 1812 that we find Col. John Stevens, of Hoboken, New Jersey, with a wonderfully clear grasp of the transportation question, wearing his life away trying to secure the building of a railroad, "on piles," from Albany to Lake Erie. In 1825 the Stockton and Darlington Railroad in England, thirty miles long, was the first to carry passengers. It was on this road that, when it came time to light the fire in the locomotive on its first trip, no tinder could be found; so one of the employees drew a burning-glass from his pocket, and obtained fire from the sun,—which was highly appropriate as well as poetical. Then came Stephenson, with his thirty-six-miles-an-hour locomotive, steam-blast and multi-tubular, the basis of subsequent engines.

MEANWHILE AMERICA WAS NOT IDLE.

Meanwhile America had been working along original lines and produced several engines that were noted for their ingenuity, if not their entire success. The South Carolina R. R., in 1830, used the Best Friend—engines were called by familiar names in those days—which looked like a "gigantic beer bottle." It was from the safety-valve of this engine that the traditional negro was blown when he sat on the valve "to stop the noise." When the second engine was built, a barrier of cotton bales was erected between the engine and coaches, for protection, and passengers were assured that the safety valve was "out of reach of any person but the engineer." The same year Peter Cooper ran his little Tom Thumb, which weighed a whole ton, twenty-six miles and back, being beaten on the return trip by a team of gray horses, due, however, to the slipping of a band from a wheel. In 1831 came the memorable trip of the "DeWitt Clinton" and its mail-coach train from Albany to Schenectady. It was a roaring success, despite the fact that the passengers were bruised black and blue by being jerked from their seats whenever the train started and stopped, and that the umbrellas raised as a protection against the pitch-pine cinders, were burned within the first mile, the passengers being then kept busy beating out fire on one another's clothing.

After these early experiments, American railroads adopted the English type of locomotive, the first one imported being the Stourbridge Lion, so-called because it had the head of a raging lion painted in red on the front of the boiler.

FANATICAL PREJUDICE CANNOT KILL A GOOD IDEA.

It was only a century ago, or less, that these heroic attempts were being made by a few brave spirits to solve the insistent problem of steam propulsion; but the opposition excited, and objections raised, belongs properly to a period a thousand years back, instead of one almost within memory. It was said that the smoke from the engine would kill all the birds; that the sparks would set fire to everything within range; that passengers could not breathe in a train moving so rapidly, or they would be made worse than sea-sick; that the "brains of business men were addled" by the swiftness of their journeys. Wordsworth was furious against the "profane innovation," and Ruskin considered it an "invention of the evil one." As late as 1842, Dorchester, Mass., in town meeting, solemnly attempted to avert "so great a calamity to our town as must be the location of any railroad through it." But neither disparagement, ridicule nor prejudice could stay the working out of a principle which was to place mankind on a new plane, and revolutionize race progress.

CITIES SPRINGING INTO LIFE AND GETTING NEIGHBORLY.

When once the idea had taken root, railroads were built out from the great centers in all directions, and large cities hastened to become connected, by means of the magic iron bands, with one another. Then smaller towns, not on the main lines of travel, laid claim to neighborliness, and got into locomotive touch with their big brothers. Finally, with superb daring and faith in its own destiny, the railroad pushed out into the uninhabited regions, finding no mountains too high to climb, no rivers too wide to cross, no distances too great to cover; and in its victorious course, creating towns, settling states and countries, and hastening the day of universal brotherhood.

RAILROADS THAT SPAN CONTINENTS.

There are no more thrilling or romantic stories than those of the great transcontinental systems, the masterly brains that planned them, the marvelous engineering skill that built them, and the staggering difficulties that had to be overcome. There is the Union Pacific, spanning, with its connections, the United States, whose last golden spike, driven in 1869, meant, with other transcontinental routes to follow, an eternal highway to the Golden Gate. There is the Canadian Pacific that, under our very eyes, is building an empire. There is the tremendous Trans-Siberian system across Asia, without which Russia would fall to pieces; and the ''Cape to Cairo'' Railway, the dream of Cecil Rhodes, that bisects Africa, penetrating to its darkest depths, and bringing to the land of deepest need the light of a new hope. And what about the benefits that may flow from the entrance of the locomotive which is even now pushing its way through Turkey, Palestine, and into the heart of Persia, the cradle of the race! It will not re-create the Garden of Eden, though it will reach the reputed location, nor would we want it to; but it will quicken ancient peoples into life, and start them upon another course, which—who knows?—may be the beginning of a new cycle of development.

A SUBJECT THAT LEADS INTO INTERESTING PATHS.

It would be intensely interesting to go a little more deeply into the subject of railroad construction, maintenance, and equipment; the fascinating speed record; the overcoming of difficulties of operation, such as snow fighting; tales of heroism, adventure, and narrow escapes; the growth and perfection of safety appliances and the reduction of accidents, until some railroads now report immunity from fatalities to passengers, for years at a time. Only a point can be touched upon, here and there, which, however, it is hoped, will lead many readers to go more fully into the wide fields of inquiry that they suggest.

MILEAGE AND COST.

The total extent of the railroads of the world is over six hundred thousand miles, of which America boasts one half, and the United States two hundred and thirty-six thousand. It costs England the enormous average of $271,000 per mile to construct her railroads, more than any other country has to pay. In the United States the average cost per mile is only $69,000.

A ROADBED AS EASY AS A ROCKING-CHAIR.

The roadbed has been improved, until now it is as solid as rock, yet resilient, so that the motion and ‘‘pounding’’ are reduced to a minimum. Wooden ties are still used, as no substitute can be found that will answer all requirements; but, as the three hundred million cubic feet of timber that goes annually into ties constitute a fearful drain on the world’s forests, preservatives are now being used to lengthen the life of ties, and, under the stress of need, some other material will doubtless be found or invented that will answer the purpose. Steel ties are being experimented with, as are ties of glass, cement, and other substances.

FORTY DIFFERENT KINDS OF CARS.

There are forty distinct types of cars, seventy per cent. of them for freight service, twenty per cent. for passengers, ten per cent. for mail and other uses. The first sleeping car was devised in 1836; the first Pullman sleeper went into use in 1864. In 1898 the first all-steel car was introduced, and now there are two hundred thousand of them in use in the United States. The standard length of the box car, for freight, is thirty-six feet; and the length of the passenger car from fifty-five to sixty-five feet. The latter holds an average of sixty passengers. The brakes are operated by compressed air, and are quick-acting, being applied to every pair of wheels simultaneously, and are under the control of one person, the engineer. All cars now have automatic couplers and spring buffers, and all important passenger trains are ‘‘vestibuled.’’

FROM ONE TON TO HUNDREDS.

Since the time of Peter Cooper's Tom Thumb, of one ton weight, locomotives have grown to a giant's size and power. The Rocket weighed four and a half tons; by 1850, the weight of a first-class locomotive had increased to thirty-six tons, and, a quarter of a century later, had reached the prodigious figure of fifty tons.

In the United States there are many types: the "Mogul," with its two truck wheels and six drivers; the "Consolidation," which added two driving wheels; the "Atlantic," with four truck wheels, four driving wheels and two trailing wheels; and the "Pacific," which added two drivers, but left off the trailers. These ran in weight well up to two hundred tons. Then came the "Mallet Compound," two four-cylinder, balanced, compound locomotives, built for the Atchison, Topeka and Santa Fe Railroad. One is used for freight traffic, and the other for passenger trains, and each is the heaviest of its class in the world. The length of the freight locomotive over all, including the tender, is one hundred and twenty feet, and the weight, including the tender, is four hundred and twenty-five tons,—"the weight of a complete train, including the engine, which would have been considered heavy a few years ago." The heating surface of its boilers, which is the measure of its power, is six thousand, six hundred and seventy-four square feet, as compared with the four thousand, four hundred square feet of the "Pacific" type.

Where the limit is, no man can tell; but of course there is a limit, set by existing tunnels and bridges, and by the weight that can be carried on axle journals without undue heating, as well as by many other considerations.

WONDERFUL SPEED RECORDS.

What is the highest speed record? That depends. Is it a "burst of speed" that is meant, or an average maintained over a long distance? And what were the conditions of track, roadbed, weight of train, type of engine, even the direction of wind? Every item has a bearing, and affects the results. So only a few of the recorded instances will be given; those which are always mentioned by railroad men when the subject is brought up.

A comparatively short continuous run was made, in 1897, by the Black Diamond express, which covered forty-four miles in thirty-three minutes,—eighty miles an hour. In 1902 a train on the Chicago, Burlington and Quincy railroad ran fourteen miles in nine minutes,—ninety-eight and seven-tenths miles an hour. For long hauls, in 1895, an English average of sixty-three miles was maintained over five hundred and forty miles, and in the United States, sixty-four miles an hour over the four hundred and thirty-six miles between New York and Buffalo. In 1909, the Twentieth Century Limited rushed from New York to Chicago, nine hundred and sixty-five miles, at an hourly average of almost sixty-three miles.

For "sprints," the three following instances are emblazoned in letters of light: In 1893 the Empire State express ran at the rate of one hundred and twelve miles an hour, for one mile, covering the mile in thirty-two seconds. A Philadelphia and Reading railroad train, in 1904, ran for four and four-fifth miles at the rate of slightly over one hundred and fifteen miles an hour; but this was not equal to the phenomenal speed said to have been made by a train on the Plant System, in Florida, which covered five miles in two minutes and thirty seconds,—one hundred and twenty miles to the hour!

THE COMING ERA OF ELECTRICITY.

Elevated railroads, mountain railways, and the enormous subject of electric roads have not been touched upon, but present interesting chapters in railroad history. Many of the great railroads of the United States are partially "electrified," especially in radii around the great cities,—the Pennsylvania railroad's entrance into and under New York being the most notable example. The network of interurban electric lines that is becoming more finely interwoven every year, and the tremendous increase in electrical equipment made by the steam railroads lead many to think that the time is near at hand when electricity will entirely displace steam, at least in passenger travel.

To mention only one or two instances illustrating the trend toward an "electrical age": The Great Northern railroad has recently purchased an electric locomotive of a hundred and fifteen tons weight; and the New Haven railroad has put on a locomotive guaranteed to run at a maximum speed of eighty-six miles an hour.

A speed test has been made in Germany, on the Marienfelde-Zossen experimental system, in which an electric locomotive developed and maintained for some distance, the almost incredible speed of one hundred and thirty miles an hour! And the era of electricity is only dawning!

SAFETY OF BILLIONS.

On the railroads of the United States there were carried in a recent year nearly a billion passengers; and of this tremendous total only two hundred and forty-nine lost their lives through accidents. No further commentary is needed on the perfection to which safety appliances, and the development of mechanical and personal efficiency, have brought the railroad system.

THE "RAILROAD QUESTION" AND BROTHERHOOD.

The "railroad question" in the United States, in its intimate social, economic and governmental relations, is one of the most important with which a nation has ever had to deal. Especially in the transportation of commodities is it so closely enmeshed with every farming, mercantile, and manufacturing interest, and, in the matter of Federal and State control, so weighty a concern of government, that it touches, in a very personal way, the daily life of every citizen. As a large factor in "the cost of living," it reaches our pocketbooks; it supplies us not only with necessities but comforts and enjoyments; it brings us into touch with every other member of mankind, and unites us all in an indissoluble bond of brotherhood.

CHAPTER LII.

Railway Block-Signals.

UNHESITATINGLY RUNNING A RISK.

COMFORTABLY seated in our luxurious railway cars while being whirled through space at forty, fifty, or sixty miles an hour, how little we realize what dangers constantly lurk in our path and by what unfailing means they are continually being averted! With hundreds of trains dotting as many miles of track, madly rushing night and day in either direction, taking curves and making switches, darting through tunnels and crossing brides, all at hardly slackened pace, the dangers of modern railway travel are certainly real. Yet we board "flyers" every day without the slightest hesitation or fear—certainly with less of either than our grandfathers felt, when they climbed into their slow-moving stages. Why? What causes this seeming unconcern for safety, this unhesitating risk of life and limb? It is unquestionably due to our great confidence in the well-nigh perfect manner of modern railway construction and the equally unerring method of railroad operation. In the latter, the engine-drivers, whom we all implicitly trust, constitute a most important element. But the man at the throttle could make very little headway nowadays without the man in the tower. The signal men, therefore, and the present methods of railway signaling, constitute the second great factor in modern railway operation; and it is difficult to say which of the two—the engineer or the signal by which his train is run—is really the more important in assuring speed and safety on our railway journeys.

THE SEMAPHORE BY DAY AND LANTERN BY NIGHT.

Railroad signaling was at first a very clumsy affair—as clumsy as the first telegraph, the first locomotive, and other first things. Indeed, the primitive system of railway signaling and the very first telegraph were identical. In either case, a line of towers within sight of one another, and surmounted by tall posts, constituted the "system." On these towers the movable arms, called "semaphores," were operated entirely by hand, each attendant merely repeating whatever signal might be visible at the nearest post. By this method of successive transmission, somewhat suggestive of the worm's mode of propulsion, both railroad signals and messages were at first communicated. Flags would sometimes be used instead of semaphores in the daytime, and lanterns during the night—if, indeed, trains braved the night in those early times of signal tracks and few safeguards.

But either of these methods of railway signaling necessitated so many operators that its maintenance must have been very costly. Every signal had to be set by hand, and, even when an operator would run back and forth from tower to tower—as was actually done in some instances—this expense could not be greatly decreased. Besides, as traffic increased and speed was becoming an important factor in railroad travel, the "relay-signalman" proved inadequate to changing conditions. But invention, "the child of necessity,'' came to man's aid, and new automatic devices have taken the place of manual methods.

THE BEGINNING OF MODERN SYSTEMS.

The present wonderful system of railroad signaling, by which one central operator controls and keeps in touch with every train leaving or entering a busy station over scores of tracks, is a comparatively recent development. Indeed, since it depends entirely upon telegraphy and electricity, it could not have preceded the invention of the one nor the discovery of the other. It was just before the middle of the last century that the automatic appliances which developed into the modern ''block system'' began to be used in railroad signaling.

THE BLOCK TOWER PLAN.

Previous to this, however, ''block towers,'' were very much in evidence. These, placed several miles apart beside the roadbed, were connected by the electric telegraph and placed in charge of two operators who relieved each other every twelve hours. Two signals, indicating either a clear way or danger, were displayed from each tower. When a train passed a given tower, its operator displayed the danger signal until the operator in the next tower ahead telegraphed that this particular train had passed his post. This was intended merely to avoid collisions by keeping trains sufficiently apart. It was not always successful, however, because its efficiency depended entirely on the operator's correct interpretation of signals or messages; and men, especially when tired, will make mistakes.

THE INGENIOUS BLOCK SYSTEM.

In the block system, mechanical contrivances are used to help eliminate the possibilities of error due to the human element. This system is either wholly or partly automatic. By the latter method, after an operator has displayed the danger signal, a mechanical device prevents his displaying ''clear'' before the operator in the tower ahead has thrown his signal to danger. The electric contrivance in this case interlocks the operator's lever till the train has passed the next tower, when it is released automatically by the same lever that works the ''clear'' signal. This interlocking device, however, still depends on human agencies, since the levers must be worked by hand. On roads where traffic is heavy and speeds are high, the possibility of confusion still makes accidents possible.

It was to eliminate this last element of risk that the method of complete automatic railroad signaling was introduced. This system has already proved to be the most efficient and the least expensive to operate, and in the United States alone about twelve million miles of track are equipped with it. Its greater economy permits closer signals and hence greater safety to passengers, apart from its other element of reliability. It is a most ingenious device—one of the wonders of electrical engineering—and rather too technical for laymen to understand in detail. Besides, there are numerous variations of the original invention. But a few general features may be briefly outlined.

HOW TRAINS THEMSELVES OPERATE SIGNALS.

Automatic signaling by the trains themselves depends upon an intricate chain of magnets lying along the rails. These are so constructed that, by means of electricity, the semaphores connected with a given signal-battery are always set ''clear'' so long as no train is directly over the magnets. The moment any wheel presses upon them, their magnetic current is deflected and the ''clear'' signal is replaced by that of ''danger;'' and as soon as every wheel of the train is off that section of the track, the safety signal goes up again. In other words, the two signals are so balanced that they indicate ''danger,'' when the magnetic force is cut off from action by the passing wheels, but swing to ''clear,'' as soon as the regular circuit is again established. Hence, any break in the system acts automatically to hold up approaching trains. Another unique advantage of this circuit-battery system is, that, even if a passing train has broken in two or dropped a car, as sometimes happens, the danger signals would still be set against any other train and can not be lowered until all obstructions are out of the way.

THE SIGNAL OF A SIGNAL.

As these signals are comparatively close together, they could not be heeded by fast-running trains in time to avert possible danger, since it usually takes about two thousand feet to bring a modern express train to a full stop. Therefore, preliminary warning signals are set up at that distance ahead, which say to the engineer, ''Proceed at slower speed.'' He then looks for a full-stop signal, and has his train under control. This is called ''permissive blocking,'' in contradistinction to the ''absolute blocking.'' Frequently these two signals are placed on the same posts, and one may observe two extended arms over a track go up and down with the passage of trains. One of these, painted red, says ''danger'' when horizontal; the other, commonly green, says ''caution.'' When both arms are horizontal no train may pass that point; when both are down, the section of track between this and the next signal point is perfectly clear, and trains may run at full speed. In connection with these automatic semaphores, and depending upon the same electric power, numerous other devices have been devised for displaying colored lights, ringing bells, firing explosives, and making other seemingly mysterious noises, automatically, that secure the attention of the engineer, and make him, if possible, more alert than ever. For eternal vigilance, especially on the railroad, is the price of safety.

CHAPTER LIII.

Canals.

A LOG AND A POLE.

WHEN, in prehistoric times, a man found it necessary to leave his cave, in pursuit of game or to chase an enemy that had become too familiar and insistent for comfort, he must have soon discovered the utility of the stream that flowed past the entrance to his den, or the lake on whose shores his little brown children played. A log and a pole carried him further in a day than he could have walked in a week, and far more easily.

AT THE END OF THE LAKE.

But when he reached the end of the lake, or a waterfalls checked his swift progress on the river, and the enemy still eluded him or, worse yet, was close on his track; or game in tantalizing abundance could be seen ''over further''—what then? We can fancy him climbing a ridge and gazing longingly at the next lake or the on-stretch of his own river, then, with a grunt, turning back to his log and working his way, disgustedly, home. If, however, he belonged to the class of those who never give up, he would hunt another log and continue on his way, rejoicing. His descendant, in later generations, having passed beyond the log stage into the canoe age, wouldn't stop for a little thing like a few miles of land-barrier, but would pick up his canoe and ''portage'' across to the point where he could continue his interrupted journey. But the idea must very soon have entered the early brain that a water passage at certain points, where a canoe could carry him, would be an immense improvement on carrying the canoe across dry land!

WHERE TWO NECKS WERE BROKEN.

Then, still further on in the development of restless humanity, men of intrepid spirit left safe and familiar shores behind and tempted unknown seas. How tantalizing it must have been for these early navigators to find their way to fame or riches or liberty interrupted, if not barred, by two narrow necks of land where the oceans almost met and where a few miles of waterway would save months of time and the perils of a long journey around two continents! Such conditions, indeed, were so intolerable that, after centuries of countless loss of ships and lives, and when the needs of international commerce and the desire for international peace could no longer stand the strain, nations arose and commanded that the mighty barriers be broken down. And behold the Suez and Panama Canals, that make possible a continuous journey around the world through the middle belt of commerce and civilization!

THE LARGEST CANAL SYSTEM IN THE WORLD.

It is easy to see how the building of canals was one of the earliest necessities and enterprises of the human race, as travel by water far antedated all other artificial means of getting from place to place. So far back that it reaches into legendary lore, there are indications of a canal system built by the predecessors of the Pharaohs, seven thousand years before the Christian Era; and the Chaldeans and Chinese were almost as prompt in digging waterways. It is undoubtedly true that these channels were first excavated for irrigation purposes; but it could not have been long before they were utilized in transporting people and products from place to place, and, by connecting and "canalizing" rivers, were expanded into a network of routes for travel. Indeed the "Grand Canal" of China, which, including its canalized rivers, is a thousand miles in length, constitutes the longest navigable artificial waterway in the world; and the entire canal system of China, comprising over five thousand miles, is indispensable to the very existence of that teeming kingdom.

A FACT THAT IS PROBABLY A SURPRISE.

The "Royal Canal" of Babylon was dug about 1700 B.C., and enlarged by Nebuchadnezzar about 600 B.C. It was near this time, also, several hundred years before Christ, that the *first* Suez Canal was begun, to be finished later by one of the kings of Egypt. In our pride of present-day achievement, it is somewhat of a surprise, not to say shock, to hear of another canal than our own vaunted "Suez" at this strategical point; but it was undoubtedly there, and in use, until the Mohammedans found it too subversive of their retrogressive policy, and ordered its destruction in 767 A.D.

EUROPEAN CANALS.

Of all the countries of Europe, Holland has made the most comprehensive and consistent use of the canal principle, thereby maintaining her independence and commercial importance. Her more than two thousand miles of canals are kept in most efficient condition; and her magnificent ship canal which makes a seaport of Amsterdam, is an engineering feat of immense magnitude.

France has three thousand miles of canals, including the waterways that connect the Mediterranean with the Bay of Biscay. Germany has over thirteen hundred miles of canals, and these unite her splendid rivers at nearly every point where commerce needs a union. Her great ship canal, the Kiel, joining the Baltic and North Seas, cost forty million dollars and is now being enlarged, at enormous expense, to accommodate the latest "Dreadnoughts." The canals of the United Kingdom cover twenty-eight hundred miles.

CANALS IN CANADA AND THE UNITED STATES.

On this side of the sea, Canada has spent one hundred and ten million dollars on artificial waterways—a far-seeing investment and, in proportion to her population, the largest on record. The United States has spent only twice that amount, not including, of course, the Panama Canal.

The first canal in the United States was built, in 1793, around the falls of the Connecticut River at South Hadley Falls, Mass. The boats were run into a movable box filled with water, and hauled up an inclined plane by cables. George Washington was greatly interested in the subject of canals, his sagacious mind recognizing their great importance in developing the resources of a new country. He is said to have expressed a favorable opinion as to the feasibility of a canal from Lake Erie to New York, though his efforts were especially directed to getting an outlet from the Ohio region to tide water by a more southern route; but that across New York State was found to have the logical, indeed inevitable, trend. The opening of the Erie Canal in 1825 was an epochal event. It secured for New York the domination of the Atlantic seaboard and focused upon that city the commerce of the western states.

The United States has built another canal of transcendent importance. It is the Sault Ste. Marie, only two miles in length, connecting Lakes Superior and Huron; but the tonnage of vessels passing through it is the largest in the world, being, in 1910, over forty-six million tons. The next largest in the world is that of the Suez Canal, over fifteen million tons.

A ROUTE OF INCALCULABLE VALUE.

The present Suez Canal, the second to be built connecting the Mediterranean and Red Seas, is a work that taxed the most consummate engineering skill of the time. It is ninety miles long, without locks, and

THE SUEZ CANAL.—The engineering involved in the construction of this canal, was little more than children employ in digging through sand. Compare the work on the Panama Canal.

cost a little over one hundred million dollars. It has a depth of thirty-one feet, a width at the bottom of one hundred and eight feet, and at the surface of four hundred and twenty feet. The passage of ships can be made in eighteen hours, the use of powerful electric lights allowing the journey to continue at night, uninterruptedly. The amount saved to commerce by the Suez Canal since its opening in 1869, by obviating the long, dangerous journey around the Cape of Good Hope and reducing the route of the immensely valuable Oriental trade one third, is simply incalculable.

A SAVING OF THOUSANDS OF MILES.

The Panama Canal, now being completed, will effect changes of far more stupendous influence on world commerce and the wealth and peace of nations, and presents engineering problems to which those of the Suez Canal were pigmies. A waterway across the Isthmus of Panama had been the desire, or at least the dream, of the past four centuries; but construction was not begun until 1881, when the French undertook the task. Failing for lack of funds, the United States took up the work in 1904 and has brought it nearly to completion. The canal will be forty-one miles in length, forty-one to forty-five feet in depth, and five hundred feet wide at the surface. It is a lock-canal, the locks at Gatun bringing the summit level of the canal to eighty-five feet; nothing like their magnitude has ever before been attempted.

It is estimated that the total cost of the canal will reach three hundred and seventy-five million dollars—including the forty millions paid to the French government and the sum of twenty millions spent for sanitation.

The average reduction in time that will be saved between the more important commercial points from United States' ports is five thousand miles. The average reduction from European ports is twenty-six hundred miles. It is difficult to realize, and impossible to foretell, what important changes in commerce, in war, in international relations, the completion of the Panama Canal will gradually bring about; but they cannot fail to be beneficial to all mankind.

CANAL MILEAGE OF AMERICA AND EUROPE.

The canal mileage of Europe is placed by the best statisticians at over thirteen thousand miles; of the United States at four thousand four hundred; of Canada, five hundred and thirty-five. The total of the world's canals reaches twenty-six thousand miles—almost exactly the circumference of the earth at the equator. The cost of the world's canals has been over two billion dollars—a tremendous expenditure, but one that has brought rich returns on the investment.

A TWENTIETH CENTURY SUBJECT OF STUDY.

If we add to the twenty-six thousand miles of canals mentioned above, the one hundred and twenty-seven thousand miles of navigable rivers in America and Europe, we have a gigantic waterway system of untold worth. With the advent of the railroad, water transportation has suffered a partial eclipse; but men are just awakening to its unsurpassed commercial value and to see that nature and the art of man, working together, have provided a comparatively inexpensive, easy, efficient, and extremely available means of transportation that should no longer be ignored. The subject of inland waterways, including the use of canals and rivers for irrigation, drainage, and power, as well as transportation, is one of the greatest importance and is certain to be a twentieth century subject for thought, and worthy of the most careful study. Careers of great usefulness are awaiting those who can help solve some of the interesting problems presented by the question of Inland Waterways and allied subjects.

CHAPTER LIV.

The Automobile.

WHEN THE AUTOMOBILE WAS NEW.

IT is sometimes a disadvantage to have become too familiar with anything we would understand aright. Even when such familiarity does not breed the proverbial contempt, it is sure to lead to indifference, which is but little better. The career of the automobile is a case in point. From the time when people would run miles to see them to this day and age, when most of us run even farther to avoid them, automobiles have become a sight so common that even small towns allow them to pass unnoticed. Even the farmer gives them no more than a passing glance, unless it be to say something impolite of the siren's toot or the smoke and dust that follow in their wake. Even the unsophisticated cow by the roadside is no longer disturbed—she has long ceased to be startled—by those ''horrible horseless carriages.''

THE POSSIBILITIES OF THE AUTOMOBILE.

And yet, the greatest achievements in the construction, speed, and uses of automobiles are only now coming to be realized. Compared to the commotion caused by passing cars in their early days, what wonder and amazement would the present ''monsters of the road'' excite in us, were not our curiosity dulled by too much familiarity. Yet the actual possibilities of the automobile, for every kind of vehicular traffic, are far greater today than its most enthusiastic devotees ventured to predict in the time when the contrivance was new. But this has generally been the fate of our most important inventions: attracting most attention in their early stages by their novelty, and gradually winning more lasting favor by their usefulness when the initial excitement is over and all superficial interest has been satisfied.

THE EVOLUTION OF THE AUTOMOBILE.

Man's efforts to "annihilate space" by means of rapid transit must have begun soon after his appearance on this planet. In this long history, the beginnings of which are not recorded, the invention of steamships and railroads constitutes one great chapter; the invention of airships and horseless vehicles forms another. The first turning point was passed in the substitution of mechanical for animal power in locomotion; the second marked the realization of an individual, in place of a public, means of conveyance. Trains and steamboats, it is true, can carry one to the ends of the world, but only in automobiles may he go subject to his own volition. Just as the former are superior in speed to animal means of transportation, so do the latter excel them in point of convenience. Indeed, so convenient and expeditious has travel by automobile become that we can only wonder how the world so long got along without it.

That it did move along somehow without the automobile till the latter part of the nineteenth century is certain, however, since the horseless carriage had not previously come into anything like general use. Yet, as early as the thirteenth century, the possibility of horseless vehicles was foreseen, for to a Franciscan friar, who died at the close of that century, belongs the honor of a remarkable prediction. It was Roger Bacon who wrote, more than six hundred years ago: "We will be able to propel carriages with incredible speed without the assistance of any animal." So unthinkable did such a thing seem at that time, that this prophecy failed to attract the slightest attention, and it is only in modern times that its full meaning has come to be realized.

The very first to body this imagination in tangible form was a certain Johann Haustack, of Nuremberg, living in the seventeenth century. To him credit is given for making "chariots going by spring and covering two thousand paces an hour." As there was no steering device on this "chariot," the latter could travel in a straight line only. Wind-driven vehicles were tried in Holland about the same time, and these "ships on wheels" were probably more manageable than Haustack's "chariots." Steam power was not applied to automobiles—how could it have been?—before the invention of the steam-engine. Although an Englishman, the famous Newton; an Italian, Giovanni Branca, and a Chinese missionary, Verbiest, all experimented with steam-propelled carriages, it was Nicholas Cugnot, a Frenchman, who, somewhere about 1770, invented the first steam automobile. Cugnot's machine had three wheels, steering-gear, and a reversible engine, and could carry a load of two and a half tons at the dizzy speed of quite three miles per hour.

With Cugnot's crude roadster, however, the real development of the automobile may be said to have begun. The first practical improvements were made in England, where, during the second half of the eighteenth century, steam-propelled vehicles came into considerable use. One of these steam coaches, bearing the inauspicious name "The Autopsy," ran regularly between two English towns in 1836, covering four thousand two hundred miles and carrying more than twelve thousand passengers without mishap. Since the middle of the nineteenth century, France has done more than any other country—save, perhaps, the United States—toward automobile improvement. When a Frenchman (one Amédée Ballée) built an omnibus which, in 1895, made seven hundred and forty-five miles in ninety hours, the modern automobile had surely arrived.

So far, however, steam was the only motive power used in horseless vehicles. With the successful application of gas in propelling automobiles, in the last decade of the nineteenth century, a new era was reached. It remained but to introduce electricity in the operation of automobiles, which soon followed, and the three fundamental types of horseless carriages known today were already in practical use.

Since the closing years of the last century, rapid strides in automobile construction and improvement have been made in every important country, notably in France, Germany, and the United States, every year bringing innumerable new designs. But it would be neither possible nor profitable for us to follow the history of the automobile in detail. Surely, with automobiles racing—and beating—express trains running at sixty miles an hour or more, Bacon's mediæval prophecy has already been more than fully realized.

THE MACHINE WITH MANY USES.

People do not generally take to a new thing very quickly, especially when the novelty is costly; they shrewdly wait until its merits become well established. This probationary period varies greatly with the article on trial. In the case of the horseless vehicle, a decade was needed to prove it safe, practical, convenient, and economical. For the automobile encountered not only fear and timidity; it met with concerted opposition from railroads and other public carriers, whose business it threatened to impair. Besides, the horseless carriage had to overcome considerable unfavorable legislation before it was allowed to share the use of the road with the horse on terms of equality. These and other forms of opposition born of man's natural conservatism—some of which are still to be overcome—long hindered the universal acceptance of the automobile.

To illustrate the part which conservatism played in the early days of automobiles, two instances will serve as well as dozens that might be cited. The first is found in the fact that even so progressive a city as New York long persisted in regarding the steam automobile as virtually a locomotive. Think of a guard, red flag in hand, running ahead of every steam-propelled vehicle to warn all unsuspecting pedestrians of the dangers lurking in their paths! Ridiculous as it may seem nowadays, this was at one time an actual requirement in the metropolis. Needless to say, the law, like all unreasonable laws, was more honored in the breach than in its observance. Another instance is found in the short-sighted policy which once sought to exclude the horseless carriage from public parks, on the ground that the latter were intended for horses, women, and children.

Now, however, a far saner view of the automobile prevails. Already, within a dozen years, the automobile has made its own place in the general scheme of things. Today its uses are endless. Who is not familiar with them? One need but watch, for a few minutes, the traffic of any busy thoroughfare in a large city to count something like ''57 varieties'' of motor-vehicles passing in either direction. Moving vans, express wagons, passenger cars, patrol wagons, fire engines, omnibuses, hearses, road repair shops, ambulances for man and beast, picture shows and miniature art galleries, travelling post-offices accommodating half a dozen clerks and the necessary sorting compartments, emergency hospitals equipped with surgical wards and capable of providing for several patients at once—in short, everything on wheels—can now be seen running by motors in city streets.

But, of course, the use of automobiles is not confined to cities. In rural districts the utility and consequent popularity of the automobile are duly recognized. The farmer's fear of ''those flying devils'' gradually gave way to indifference, and that finally to marked enthusiasm. A few years ago, however, the cost of horseless vehicles was rather prohibitive to the average agriculturalist. But now that five hundred dollars will buy a durable runabout, not many farmers can afford to be without one. Farmers use motor vehicles in business as well as for pleasure. For work on the farm, which requires long hours during short seasons, the horseless vehicle has been found far superior to anything formerly done by horses. Motors do not tire, nor do they eat when idle—two admirable qualities which readily commend themselves to the practical farmer. Hence, whether in hauling produce to market or bringing necessaries to the farm, whether in plowing, sowing, harvesting, or threshing, whether in road-mending or fence-making, the motor vehicle is now doing yeoman service for the agriculturalist. One ingenious farmer has learned to use his automobile even in shelling corn. Indeed, there seems to be hardly any farm labor that cannot be done nowadays by motor vehicles of one kind or another.

For ordinary routine driving, as well as for pleasure trips, the automobile is constantly winning favor with rural populations. The farmer still must go far for almost everything he needs or wants, and the time saved in daily trips means greater economy and more leisure. That farmers generally have been none too slow to appreciate these benefits of automobiling, is evidenced by the fact that over one-fourth the horseless carriages sold in a recent year west of the Mississippi went to this class of the population.

THE PLACE THE AUTOMOBILE IS FILLING.

That the automobile has at last come to stay, everyone with clear vision must now concede. It is beyond doubt one of the most important inventions of an inventing age—as important, perhaps, as the telegraph, the telephone, the railroad, or the steamboat. Although the horseless vehicle is still in its infancy, its far-reaching effects are already apparent.

Commercially, the automobile has been a godsend to the business world. It has created a new industry, one which already ranks among the chief industries of the world. The automobiles sold in the United States during one recent year (1910) numbered nearly two hundred thousand and were worth about $300,000,000. Little wonder, therefore, that such cities as New York and Chicago have special centres famous for the great number of automobile stores. In New York the ''Automobile Row'' extends from Forty-seventh to Seventy-sixth streets all along Broadway, as well as over many intersecting streets. Of part of this large district it has been said that one could not ''throw half a brick without damage to some known make of automobile.'' Sixty-one agencies, handling over a hundred different makes of automobiles, sell yearly some thirty-three thousand cars valued at about $60,000,000, from the New York ''Automobile Row'' alone. If you call to mind that there are many such automobile centres in this country—not to speak of the whole world—you may have a faint idea of what the advent of the motor vehicle has meant for commerce.

But there is another phase of its commercial significance. The automobile has created what is virtually a new enterprise. The remarkable spread of taxicabs throughout the world has led to the formation of numerous companies to finance and operate these vehicles. New York City alone has about three thousand taxicabs in operation. It is said that the receipts per car average ten dollars a day. Figure this out by the year, and then allow a snug sum for the hundreds of sight-seeing cars reaping rich harvests in the same city; finally, multiply the result by the number of large cities in the world—and what have we? Does not the product ''stagger the imagination''? But figures don't lie, they say, though they frequently do ''tell stories.''

In the present instance the story is certainly convincing.

Could we but estimate the enormous army of men engaged, directly and indirectly, in the automobile industry, the number of chauffeurs, public and private, employed in their operation, and the ranks of garage tenders and repair machinists, how many millions of men should we find earning a livelihood through the automobile! Industrially, then, the horseless vehicle is just as important as it is commercially.

As an indication of what economic benefits result from the use of motor-driven vehicles for business purposes, one New York concern reports the substitution of twelve horseless cars for forty-eight horse-driven vehicles. The former easily make all the deliveries hitherto made by the latter, and in less time. Another company, a storage warehouse, has replaced seven horses by four automobiles, and claims to have saved fifty dollars a week through this change. This saving is sufficient, it is said, to write off the original investment in the course of six years, leaving about seven years more (the normal life of motor vehicles being thirteen years) to profit by the use of horseless cars.

But it is not necessary to multiply such instances in order to show what a great saving in money, time, and labor the horseless vehicle effects. Everyone can see that a machine which ''does not age or deteriorate when idle, and requires neither fuel nor attendance when not at work,'' is economically far superior to the horse, faithful as this animal is. The motor vehicle will endure harder work for twenty-four hours each day than the strongest horse can safely do part of the day. No wonder, therefore, that automobiles are everywhere driving the old horse out of business, and that some believe we shall ultimately forsake this animal altogether.

The general use of the automobile has exercised a most beneficent influence on roads, especially in rural districts. Indeed, the good-roads agitation in America dates from the introduction of the horseless vehicle. Owing to this movement, bills have recently been introduced in Congress which provide for a national highway stretching across the continent. The automobile, coupled with the improved roads it helped to secure, has vastly extended our suburban areas and thereby relieved considerably the great congestion of large cities.

In a social way, however, neither cities nor suburbs have benefited from the use of motor cars quite as much as has the outlying country. The farmer has found in the automobile a means of social intercourse and other forms of pleasure hitherto inaccessible to him. The remoteness of the village post-office, the county schoolhouse, or the parish church up on the hill, now has no terrors for the modern farmer. His friends are now closer and his neighborhood wider, thanks to ''that devil of steel'' which takes him whither he will. With all that the machine has done for him, no wonder that the farmer is today the stanchest advocate of the automobile.

CHAPTER LV.

Steamboats and Steamships.

WHEN THE ENGINE SHOOK THE BOAT TO PIECES.

TOWARD the close of the seventeenth century, several attempts were made to apply steam in navigation; but so little was known at the time, even about steam engines, that these results, while interesting, can hardly be called successful. In every case, the vibration of the engine was so great that the boat was racked by the pulsations, and nearly shaken to pieces; it shivered in every part like the chattering teeth of a man with ague. Progress through the water was also very slow—four or five miles an hour being barely attained, and this only under favorable conditions.

THE WATER-WHEEL PADDLE AND THE WATER-CHURNING SCREW.

All early vessels were driven by means of two huge circular paddle-wheels. Experiments in screw propulsion were made in 1806, but it was 1839 before that method was practically applied. Now twin, triple, and quadruple propellers are used exclusively in lake and ocean navigation.

TWENTY YEARS BEFORE ROBERT FULTON.

The first steamboat ever built in the United States was constructed by John Fitch, of Connecticut, who made his first successful trip, August 22, 1787, attaining a speed of about three miles an hour. The boat was propelled, according to an early account, "by means of twelve bars, or paddles, five and a half feet long, which work perpendicularly and are represented by the stroke of the paddle of a canoe." Several other men experimented with steamboats, at about this time, but the results were not very satisfactory.

THE IMMORTAL FULTON.

Then came Robert Fulton and the *Clermont!* This vessel had been partly built in England, and shipped to America, where it was pieced together and completed; the copper plates of its keel were made by Paul Revere, of Revolutionary fame. It was one hundred and forty feet in length, sixteen feet beam, and seven feet deep. The engine had a cylinder twenty-four inches in diameter and a four foot stroke. Fulton's first trip was from New York to Albany, starting August 17, 1807; the speed was five miles an hour. The same year, the first boat of American construction was built by John Stevens, and was called the *Phenix.* It is a disputed question whether to Fulton or Stevens belongs the honor of the first steam ferryboat; but Fulton, in 1814, established a service between New York and Brooklyn which still bears his name. He also built a frigate called the *Fulton.* Steamboats then followed one another in rapid succession.

A SLOW BOAT WITH A RAPID NAME.

The first workable steam vessel built in Great Britain was the *Comet,* whose dimensions were forty-two feet in length, eleven feet beam, and five and one-half feet in depth. The year was 1812; the builder, John Wood, of Glasgow. Its first ambition required two pairs of paddles, and it afterwards had to be content with a single pair; but even the two couldn't put up a speed of more than five miles an hour.

RIVER AND LAKE NAVIGATION.

To come back to the United States, Robert Fulton possessed a monopoly upon the waters about New York, for several years; but, in 1824, all United States' waters were thrown open to free navigation. The result was that several river steamboat companies were formed, which were consolidated in 1832. The completion, in 1851, of the Hudson River Railroad, had the effect of greatly lessening the number of boats on the Hudson River. The few that are now in commission are luxurious floating palaces.

Steam navigation on the Great Lakes dates from the year 1818, when the *Walk-in-the-Water* was built to run on Lake Erie; and the lakes are now dotted with great boats for passengers and freight, the latter having the largest tonnage in the world.

THE FIRST STEAM VESSEL TO CROSS THE ATLANTIC.

The *Savannah* was the first steam vessel to cross the Atlantic Ocean. She was built in New York in

1818, by Francis Fickett. It was his original intention to make a sailing packet of her; but, later, she was fitted with a boiler and an engine, and, on May 24, 1819, headed for Liverpool, England. She completed the passage in twenty-seven days; but only eighty hours of this time was she under steam power, the rest of the time using her sails. She returned to America the following November, but evidently thought it was a good idea to let well enough alone, and did not venture again.

THE ERA OF THE OCEAN LINER.

It was not until 1840 that the *Britannia*, built by Samuel Cunard, steamed from England to New York. This was the voyage that marked the beginning of the ocean-liner era. In 1847 another steamer, American-built and proudly bearing the patriotic name of the *Washington,* ran all the way under her own steam from New York to Bremen, the successful execution of this feat securing a ten years' contract for carrying the United States' mail. Two years later two steamers were built to run between New York and Havre, and these captured the contract for carrying mail between France and the United States.

A dozen companies, with scores of great vessels, are now engaged in transatlantic travel; and thousands of steamships are plowing all the waters of the world. The size, power, and equipment of many of these vessels are almost incredible. Think of the *Mauretania,* seven hundred and ninety feet long and a speed record of only a little over four days, between Liverpool and New York; and the lordly *Olympic,* eight hundred and eighty-two feet in length, and built at a cost of ten million dollars!

Steam has of course revolutionized naval warfare. How a sailing vessel could ever have got within gunshot of its antagonist, maneuvered in action, or even run away, if beaten, is impossible to realize, except by remembering that the enemy was no better off.

SHIPS THAT CAN'T GO DOWN.

The modern steamship is built entirely upon a steel frame, consisting of a central support to which are affixed beams, running at right angles to the sides of the vessel. The sides curve from the floor upwards, and the various curved sections, forming the sides, are known as the "futtocks," "top-timber" and "false keel." These names were originally employed in building wooden vessels, and are, as a matter of fact, a little out of place in steel vessels; but they are, nevertheless, retained. The keel of the modern steel vessel is composed of plates, riveted together. Some vessels have two coatings of plates—an outer and an inner—which add to the strength and safety of the vessel. In all modern vessels, each room is made water-tight, so that, if the steel wall that covers one of the rooms is punctured in an accident, and the compartment fills with water, the rest of the vessel is left in safety, since the water cannot enter it. All war vessels are fitted with these water-tight compartments; and, for this reason, the armor plate of a modern vessel would have to be pierced in many places below the water line, all at once, before it would sink as the result of leakage.

HOW THE SHIP GETS INTO ITS ELEMENT.

Boats are all built in what is known as the *cradle,* or a semi-circular wooden trough. When the time comes to launch the boat, the wedges which hitherto supported it are driven away, and the supporting ropes cut. The vessel is now left on the slightly inclined plane of the cradle, which has been greased in order to facilitate the boat's passage. At a signal, the vessel begins to slide, gathering greater and greater momentum at every second, until, finally, it leaves its cradle, and with a great splash, it leaps into the water that is to be its future home. It is one of the most thrilling sights that can be witnessed.

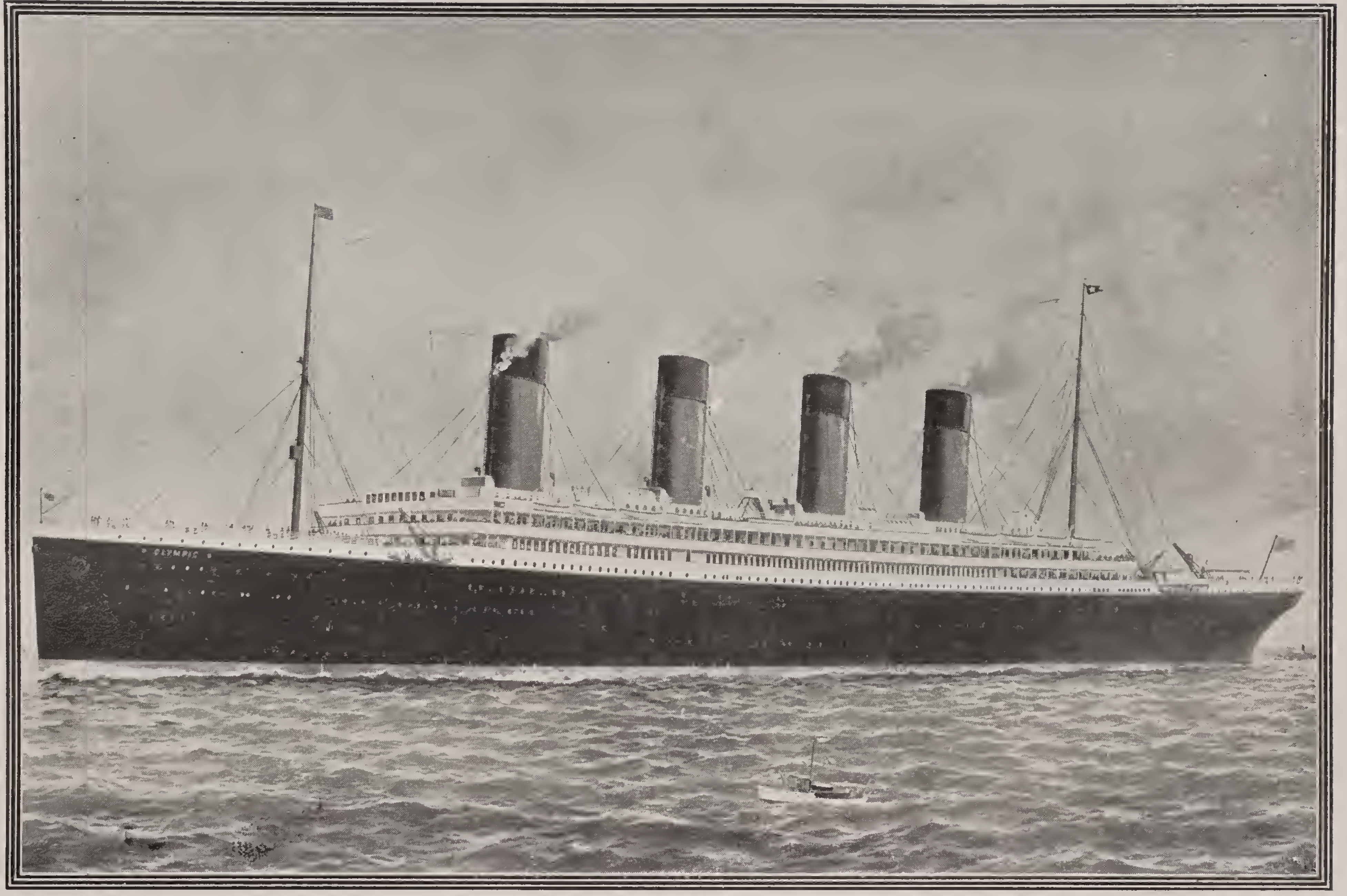
THE OLD EQUIPMENT AND THE NEW.

The older vessels were fitted with a very elaborate system of rigging—the hull, spars and standing rigging, on the one hand; and masts, sails and running rigging on the other—more than a hundred parts in all. At the present day no vessels are thus equipped, since they do not depend upon their canvas but upon their steam. A number of older sailing vessels are still to be found, however, in various odd corners of the world.

The modern vessel is fitted up with every luxury. In some of the ocean-going vessels there are elevators, and all the other comforts of a modern hotel. Almost every large vessel is now provided with a wireless telegraph apparatus, which is of great value in case of emergency, as well as enabling the passengers to keep in touch with the news of the world, on the voyage. Many of the best steamships print a daily newspaper, informing the passengers of the events in progress in various parts of the world; so voyagers may be out of touch with the land, but never out of touch with events.

HOW STEAMSHIPS PROMOTE CIVILIZATION.

One who has been brought up all his life in the atmosphere of steamships and railroads can hardly realize the enormous improvements in travel and comfort which modern navigation affords. Not many years ago, it took a month or more to cross the Atlantic, where now the trip can be accomplished in a little over four days. The effect upon trade has been very great, since many preserved and otherwise prepared food-products, which could not be kept in good condition for a month, can be shipped back and forth with comparative ease in a vessel which takes less than a week to cross. Then, too, before the Suez Canal was built, vessels going from England to India had to pass all the way around the Cape of Good Hope, the southernmost point in Africa; when sailing vessels only were



THE OLYMPIC
A Great Floating Hotel—Exclusively for Passenger Service.
Length $882\frac{1}{2}$ feet; beam, $92\frac{1}{2}$ feet; molded depth, 70 feet; displacement on maximum depth, 66,000 tons; horse-power 50,000; maximum speed, 22 knots; passengers and crew, 3,200.

in vogue, it took months and months to reach their destination. With the completion of this Canal, and the introduction of steam, however, all this has changed, and a trip of this character can now be made in a few weeks. The products of these far-distant countries could be procured neither with ease, nor in any great quantities; and many of the fruits and other delicacies which we enjoy could not be transported without the aid of steam-vessels. Had the steamship not been invented, the trade of the world would languish; nations would not keep in touch with one another; and manners and customs would be far less advanced than they are at the present day. Civilization would be impeded, for the reason that it depends, very largely, upon the relations between nations, and their free correspondence and interchange of goods and knowledge.

INCREASE IN SPEED AND POWER.

Since the *Great Eastern* first crossed the Atlantic —from Bristol to New York—in fourteen days, great progress in speed has been made. It was thought at the time that her rate of ten miles an hour was remarkable; but now ocean-going vessels have more than doubled it. Many small boats, torpedo boats, etc., exceed thirty miles an hour, and in motor boats the speed is still greater. Modern steamship travel is very expensive; and it is only the great number of passengers, and the enormous amount of baggage carried, which makes such travel profitable. An idea of the tremendous increase in the size of these boats may be gained when it is stated that the *Great Eastern,* thought at the time to be an enormous boat, was only thirteen hundred and forty tons, and four hundred horse power; whereas many of the modern boats exceed thirty thousand tons, and seventy thousand horse power. Today, it is a simple matter to cross the Atlantic; a few years ago, it was looked upon as an or-deal. This simplifying of the travel and the commerce between the countries on opposite sides of the Atlantic has had the effect of encouraging friendly relations between nations—and this, of ensuring peace. Science and the arts are also encouraged, since each nation keeps in touch with the progress of the others and thus the world advances at a faster pace than it possibly could, had all nations remained isolated and cut off from contact with all others.

CHAPTER LVI.

The Electric Telegraph

THE GIRDLE AROUND THE EARTH.

AMONG the wonderful discoveries of the past century, the electric telegraph must assuredly be given a first place, since it enables human thought to be conveyed from point to point, on the earth's surface, in the fraction of a second. Before the electro magnetic telegraph was invented, all communication had to be by means of letters and messengers; and the difference will be appreciated when we remember that during the Indian Mutiny, for example, news did not reach England as to the state of affairs until weeks afterwards, and urgent calls for help were not answered until months after the date when they were sent. For instance, an item of news which happens in Australia is read in America the following morning—or even the same day—and the same is true of every part of the world where the electric telegraph penetrates. It has "put a girdle round the earth," enabling mankind the world over to converse, assisting greatly every form of commerce, industry, science, and the arts.

EARLY EXPERIMENTS.

Experiments with the electric telegraph were begun about the close of the eighteenth century, when Lesage constructed a sort of electric device, connected by wires, to one end of which were attached twenty-four pith-ball electroscopes—one at the end of each of his twenty-four wires. Other experiments were made in 1816 and 1828, and Ampère and Persted did much toward perfecting the instruments then employed. It was finally put upon a practical working basis by Prof. Henry, of Princeton University—his system being then known as the "American system."

THEN CAME THE ARTIST-SCIENTIST.

It is to Morse, however, that we owe a practical advance, and it was due to his untiring energy that the telegraph was perfected and placed upon the market in a commercial way.

The manner in which all this came about reads like a romance. Morse had reached the age of nearly forty before he even thought of making electrical machines and decided on his life work. He had been trained abroad as an artist, and was the first president of the National Academy of Design, but was always very fond of scientific pursuits. On a memorable trip from Havre, France, to New York, the idea first came to him to apply electricity to the conveyance of news. He and a passenger had been discussing some new French experiments, and the remark had been made: "It would be well if we could send news in this rapid manner;" to which Morse at once replied: "Why can't we?" And from that moment he devoted his energies to the accomplishment of the desired end. This was in 1832. Morse had completed his first working model in 1835; but it was not until 1837 that a working line had been established. Even then but little could be done. It was not until 1843 that recognition of his efforts was forthcoming—in which year Congress voted him $32,000 for an experimental line between Washington and Baltimore.

In building this line, the wires were first laid underground, instead of on poles; but this soon had to be given up. Then, it was found that the current was so weak that the message could not be properly received. This was overcome by reinforcing the current, using what was called an ''intensity magnet,'' having many cells of a battery instead of one, and by introducing a device known as the ''relay.'' At first, a mechanical transmitter was used; but soon a simple key was employed instead—it being found that a skilled operator could manipulate this with all needed rapidity. Every time the key is depressed at the operator's end, it ''makes'' the current, and every time the key is allowed to spring up, it ''breaks'' it; so that we can ''make'' it and ''break'' it as often as necessary and with any desired rhythm. This is exactly reproduced at the recording or receiving end. This being so, two operators, by agreeing upon a certain set of signals, can spell out the entire alphabet, and, therefore, words, with great rapidity.

MANY IMPROVEMENTS FOLLOW ONE ANOTHER.

The electric telegraph instruments consist of three separate parts, or sections—the ''receiver,'' the ''sender,'' and the ''relay;'' there are several varieties of each. The current enters the receiving apparatus by means of a wire, and passes into an electromagnet, which attracts an armature of soft iron, when the current is ''closed.'' The oscillation can be regulated by means of two screws. At the other end of the lever was a pencil, since discarded, which wrote the signals on a piece of paper passing beneath the pencil. In this type of machine, a permanent record of the message was preserved. If the point of the pencil struck the paper only instantaneously, a dot was left; if the contact had any duration, a dash was produced. This was the simple type of instrument first employed; but many improvements have been made since this was invented. Ink may now be used, instead of mere indentations in the paper; and even pictures can be sent, with such accuracy that the portrait may be distinctly recognized. One of the first steps toward an improvement in the manner of sending messages was the discovery that two messages could be sent over the same wire, without interfering with each other—this being known as the duplex system. The next step was the sending of four messages; and after this it was found possible to send twelve—all over the same wire and in the same direction at the same time. In this case, the senders consist of a set of electrically driven tuning-forks, and the receivers are so adjusted that they respond only to one frequency. Other systems have since been employed, and there seems to be practically no limit to the number of messages that may be sent over the same wire at the same time, without interfering with one another. This is a remarkable triumph of electrical engineering.

ON LAND AND UNDER SEA.

On land, the wires are stretched on poles, the copper wire being isolated by glass bells (a non-conductor); but in the large cities the wires are laid underground. In water, the wires or cables have to be numerous and completely protected from the action of water—for the slightest leak would destroy the whole apparatus, and render the cable unless. When we remember that the Atlantic Cable, for example, is more than two thousand miles in length, the difficulty of completely protecting such a span of wire is manifest. The following brief description, by Lord Kelvin, of the early Atlantic Cable will be of interest, showing what an enormous task this must have been:

"In the year 1857, as much iron as would make a cube twenty feet wide was drawn into wire long enough to extend from the earth to the moon, and reach several times around each globe. This wire was made into one hundred and twenty-six lengths of two thousand five hundred miles, and spun into eighteen strands of seven wires each. A single strand of seven copper wires of the same length, weighing in all one hundred and ten grains per foot, was three times coated with gutta-percha, to an entire outer thickness of four-tenths of an inch; and this was ''served'' outside with two hundred and forty tons of tarred yarn, and then laid over with the eighteen strands of iron wire in long, contiguous spirals and passed through a bath of melted pitch.''

SENDING PICTURES BY WIRE.

The possibility of transmitting across great distances, handwriting, portraits, etc., by means of the telegraph, has been alluded to. As this appears so incredible, it will be of interest to explain how it is accomplished. One method, known as ''Casselli's pantelegraph'' (so named because the reproduction may be as large as the original or larger), is constructed as follows: The message to be sent is written with an insulating ink on a piece of tinfoil, and received on a sheet of chemically prepared paper, upon which a blue dot is left at each current-impulse. The motions of the marking style at the two stations are controlled by similar pendulations. In the Denison system, these pendulums are forced to vibrate together through the control of electro-magnets operated by the same alternating current. The most recent and useful of these arrangements is the ''telautograph.'' The message is reproduced as fast as it is written. Drawings or sketches are transmitted with great facility; in fact, every motion of the sending-pen is instantly followed by the receiver. Some of these are in use in the United States Army.

Among the latest improvements may be mentioned "telephotography," or photography at a distance, by means of the electric telegraph outfit; and "television,"—now being perfected by Mm. Rignoux and Fournier, of Paris, in which it will be possible to see objects at a distance by means of the electric line, and with the addition of certain accessory pieces of apparatus. When this has been perfected, vision at a distance will be an accomplished fact.

CHAPTER LVII.

The Atlantic Cable.

WHEN FOREIGN NEWS WAS OLD NEWS.

THE laying of the Atlantic Cable, connecting the old and the new worlds, was the most important forward step in civilization, and the most daring electrical feat ever undertaken up to that time. Before the year 1865, when the first successful cable was laid, all interchange of news between the two countries and between the two worlds had to be by means of letters and belated newspapers, carried by slow-going boats. It was often several weeks after important events happened that they were heard of in the United States; and, in the case of faraway countries, such as China or Australia, the time was much greater. In these days of the instantaneous telegraph, it is hard to realize this; for we now have the latest news from all over the world, gathered into one sheet and read almost as soon as it has happened. But it is easy to see the enormous advantages which a cable of this kind rendered possible—the immediate interchange of news and of thought, helping civilization and commerce in a way not possible by any other means.

THE TABLELAND AND THE CABLE LINE.

The idea of an electric cable between England and the United States was first suggested by Prof. Morse, inventor of the telegraph, in 1843. A number of years elapsed, however, before any steps were taken to put his idea into operation. In the interval, Lieut. Maury, of the U. S. Navy, had discovered that the ocean-bed lying between Ireland and Newfoundland was a nearly level tableland, and consisted of a kind of soft ooze. At the same time, Cyrus W. Field and others were discussing cable possibilities, from the electrical standpoint. The result was that a company was formed in 1856, to which the United States Government and that of Great Britain gave liberal guarantees. The first attempt at cable laying was made in the following year, 1857, but ended in complete failure. The next year, however, 1858, a cable was laid, and it was hoped that success had finally been achieved.

TRIUMPHANT SUCCESS OF THE MAN WHO NEVER GAVE UP.

In this, however, the founders were disappointed. The current sent through it was so weak that it took sixty-seven minutes to transmit the ninety word message of congratulation which the Queen sent to the President; and, after a few more messages had been sent, the cable became dumb.

As a result of this failure, no further attempt was made until 1865, when a new company was organized. The paying-out journey began at Valentia, but the cable suddenly snapped, as the result of an accidental strain, when the vessel carrying it was one thousand and sixty-four miles at sea. A long-continued effort was made to grapple the broken cable, but, after fruitless trial, the vessel was obliged to abandon the effort for the season.

The following year, another attempt was made, when the Great Eastern, carrying a cable both lighter and stronger than the previous one, successfully laid it from coast to coast. The Great Eastern also found the broken end of the old cable; it was spliced, and this was also successfully carried to Trinity Bay.

AND NOW MARCONI AND THE WIRELESS!

Today a great number of cables stretch round the world. These were formerly the sole methods of interoceanic telegraph communication; but today we have the Marconi wireless telegraph (q. v.), and it is probable that before many years have elapsed, cables will be a thing of the past.

The Telephone.

CHAPTER LVIII.

HISTORY OF THE MOST VALUABLE AMERICAN PATENT.

THE telephone, like all inventions of the kind, was the result of long and patient research, and much sacrifice on the part of the inventor. Up to the year 1875, the telegraph and the Atlantic cable were the scientific marvels of the age; but in June of that year, the first sounds were transmitted over telephone wires and the instrument was born. As yet, however, no intelligible vocal sounds had been reproduced; the instrument could not talk. This was not accomplished by the inventor (Alexander Graham Bell), until more than forty weeks later—March 10, 1876, when his machine spoke for the first time. The first intelligible words spoken over the line were: ‘‘Mr. Watson, come here, I want you,’’ spoken by Graham Bell to his assistant. That was doubtless the most joyful and excited day in Bell’s life, for his invention was now a reality, and no longer a dream of his imagination. Shortly after this, Bell obtained his first patent—‘‘the most valuable patent ever granted in this country''—and thenceforward it became only a matter of continued improvements and additions.

It must not be thought, however, that all was plain sailing. Many refused to believe that such a thing could be possible, and some of the newspapers at the time made fun of the supposed ''absurdity.'' Bell and Watson tried in every way to silence these criticisms, but it was a difficult task. They performed several sensational feats in public, in order to convince groups of sceptical reporters and scientific men who came to see the marvel. On several occasions they borrowed a telegraph wire between two towns, attached their telephonic apparatus to either end, and conversed with one another, sent selections of songs, etc.; but even then the acceptance of the idea was slow. People did not believe that spoken words could be sent over a wire! Finally, a crucial test was arranged; the telegraph line between Boston and Cambridge observatory was borrowed, and the telephone attachments made. Then, for three hours, the first sustained conversation with a telephone was maintained. A few verbal mistakes occurred, owing to the imperfection of the instrument, but otherwise the conversation was reported verbatim. The Boston Advertiser, October 19, 1876, printed these conversations in parallel columns, and doubt could no longer be maintained that the telephone had ''come to stay.''

Still, the public did not see the importance of the invention. Capital to finance the idea was not forthcoming and Bell was not wealthy, but a fortunate accident helped matters along: Bell was engaged to give a series of lectures, and the Boston Globe printed a column of news—a special despatch—received over the wire. The word *telephone* was now used for the first time; before this it had been spoken of in various ways—''an improvement in telegraphy,'' etc.; but as soon as it was realized that the invention could be applied in this practical manner, and used in business, matters took a sudden turn, and the interest increased by leaps and bounds.

In August of the following year, there were seven hundred and seventy-eight telephones in use. This was when Bell's patent was sixteen months old; and but a few months before, the only telephones in the world had been between William's workshop in Boston and his home in Somerville! But several great men now became interested. Mr. Saunders financed the newly organized "Telephone Company," and Mr. Vail became its first manager. Law suit followed law suit, as others tried to steal the patents and the ideas of Bell, but he finally overcame all opposition, and today it is one of the most flourishing and successful businesses in the world.

SCIENTIFIC CONSTRUCTION.

When the first telephones were employed, great difficulties had to be overcome before they would operate properly, and before they could be successfully put on the market. Thus, in the early years, the only way of disposing of the wires was to string them along poles—as wires are now strung in the country. But they grew so numerous that they had to be carried over the house tops as in New York City, and it was not long before eleven thousand roofs were covered in this way! Then the wires began to rust, so that, at the end of a year, nothing was left of them; or a storm would come along and wreck the wires for miles. It became necessary, in consequence, to lay the wires under ground; but then, to bury the wires was to "smother" them, in those days, or perhaps render them quite useless, since but little was known of proper "insulation"—preventing the escape of the electric current. Much experimenting was done, but the idea was finally hit upon of winding the wire in tight paper bandages; and this paper-wrapping proved the best thing ever tried; it was cheap and most effective. To-day, in the United States, there are more than six million miles of wire, wrapped in paper bandages, and placed in leaden cases, lying beneath the streets of cities. In every country throughout the world there are hundreds and thousands of miles of telephone wire; and the amount is being added to every year. Nowadays, when telephonic communication is so common, we hardly realize what it must have been when no telephones were in use. Instead of being able to talk to anyone immediately, to summon a doctor instantly in case of accident, etc., we had to send a messenger, or to telegraph, and then wait, sometimes for hours, before an answer was returned! All business was slow, and progress was hindered in every direction. Undoubtedly, the telephone is one of the most important inventions of the age, from the point of view of commerce, safety, and personal comfort.

THE PRINCIPLE OF THE TELEPHONE.

There have been many improvements in the telephone, but the principle throughout has remained the same. Spoken words are converted into electric currents, and, at the receiving end, are again converted into air vibrations or sounds, exactly corresponding to those uttered by the sender. In this way, the words are reproduced in the receiver, as sent by the speaker.

The apparatus depends upon the principle of electrical *induction.* It consists essentially of a steel magnet, around one end of which is fitted a bobbin, of fine, insulated copper wire. For a magnet of about four inches in length, by half an inch in diameter, a length of about two hundred and fifty meters, of "number thirty-eight" wire, offering a resistance of three hundred and fifty ohms, is required. The ends of this wire pass through holes in the case, and are connected with binding screws at the other end. In front of the magnet, at a distance which can be regulated by means of a screw, is the most important feature of the instrument—a *diaphragm* of soft iron, about the thickness of a sheet of letter-paper. This diaphragm is firmly attached to the mouth-piece, and vibrates to and fro with great rapidity, when moved by the voice of the speaker. In the receiving end of the instrument is a similar diaphragm, which vibrates at the same rate. The electric current is carried from one to the other by means of ordinary wires, along which runs the electric current.

Now, the principle upon which the telephone works is simply this: When we speak, certain bands or cords stretched across the throat vibrate more or less rapidly,—according to the word uttered,—and this sets in motion vibrations in the air—so many vibrations per second. To this definite rate of vibration—this *sound,* as we perceive it—we attach a certain meaning; it forms language. The air, vibrating at this definite rate, causes the metal diaphragm in the receiving end of the instrument to vibrate at exactly the same rate. With every vibration, the electric current is connected or disconnected; there are as many "makes" and "breaks" as there are vibrations of the diaphragm. These electric currents are transmitted along the wire, and, at the other end, they cause the diaphragm in the receiver to vibrate in exactly the same manner as the sending diaphragm is vibrating. In turn, this causes the air to be set in motion—to vibrate,—and, these vibrations entering the ear, cause the ear-drum to vibrate, the motion is communicated to the brain by the auditory nerve, and we hear the *sound* as we would any *sound* coming to us from without.

The greatest improvement in recent years in the telephone is the introduction, in a practical way, of *wireless telephony,* that is, the use of the telephone without wires. The sending and receiving apparatus is, in this case, far more complicated, and need not be described here. (See the article on "Wireless Telegraphy and Telephony'' in this volume). In this, the sending of the electric current depends upon the *ether,* for the waves are sent across space by means of this medium, as they are in wireless telegraphy. It has been proven possible to send several messages at one time by means of the same apparatus, without the messages interfering one with another.

A late invention will enable those who care to do so, to make permanent records of all conversations which take place over a telephone; a small strip of metal is attached to the instrument, and upon this, tiny indentations are made, as upon the wax cylinder of a phonograph, by the words spoken. This can then be extracted, run through another machine, and the conversation repeated, as it is in a phonograph. It is expected that this device will prove of great value in legal cases, for detective work, etc., where it is desired to preserve an exact record of every word spoken.

CHAPTER LIX.

Wireless Telegraphy.

WHEN the telegraph was invented, it was considered one of the most wonderful contrivances ever devised by man, as indeed, it was. Then came the telephone, which startled even those who had been instrumental in perfecting the telegraph. Lastly we have, as the crowning success of all, the use of both the telegraph and the telephone without wires. There are two instruments that may be separated by thousands of miles, whose operators communicate with each other through an invisible and tangible medium! What could be more amazing, more incredible? The story of its development and present character is one of the most fascinating in the whole history of science.

ITS HISTORY AND DEVELOPMENT.

It was Professor Henry, of Princeton University, who first discovered that the spark of the Leyden jar, instead of taking a single jump as was at first supposed, consisted in a number of small backward and forward movements; that is, it was oscillatory in character. This is important to understand, because the spark is the basis of the systems used today. When an electric current is passed from one sphere to another, a field of magnetic force surrounds this current, which is proportioned to its strength. By alternating, ''surges'' are generated; that is, alternate electromagnetic and electrostatic waves, which radiate into space. In this way the waves are produced. Once launched into space, they travel through the ether, not the air, at the rate of thousands of miles a second. It is because of this immense rapidity that messages can be sent so quickly by electricity. Now, once these waves are launched into space, what happens? They travel on, as we have said, until they are caught by their proper receiver. This usually consists of a wire, so placed that it cuts the waves transversely to their line of motion. This *induces* an electromotive force in the wire, which occurs every time a wave strikes the wire; and as these follow very rapidly one upon another, a series of oscillatory currents, called ''jigs,'' are set up in the wire. The electric waves which are generally used in sending are from three to five hundred feet in length, and range from several million to one hundred thousand per second.

While several early attempts were made to signal without wires, particularly a very careful series by Professor Preece in 1882, it was not until about 1902 that a successful working apparatus was invented. This had, however, been led up to by a series of brilliant experiments; the work of Hertz, a clever experimenter who died very young; Sir Oliver Lodge, who invented the "Coherer"; Professor Fleming, who helped to perfect various wave-detectors; and Branley, whose coherer is largely used, etc.

It was in 1897 that Marconi, whose name is so well known in connection with wireless telegraphy, organized his company, and went to Rome to demonstrate before a select committee of scientists what he could do. The first experiments to test the new apparatus took place July 11-18, 1897, over the Gulf of Spezia. The results of these experiments were so successful, that it was seen that wireless had "come to stay"; and numerous experimenters set to work to improve the methods used by Marconi. Sir Oliver Lodge, in 1897, patented his "syntonic" system, which enables waves of a determined length to be picked up, and the remainder left untouched. With this, and other improvements in mind, Marconi again set to work, and established several stations for wireless telegraphy in England, and then finally, between Cornwall and Cape Cod, Mass. Nothing is known about these early experiments across the Atlantic, but it is believed that they failed, but in the same year both stations were wrecked by severe storms. The next year new stations were built, one in Cornwall, the other in St. Johns, Newfoundland—this being a lesser distance than the former. These were successful, and Marconi's dream of trans-Atlantic wireless message-sending was at last realized.

It still took time to complete the system, for, as yet, the sending station was in England, and the receiving station only on the American shores. But in 1902 the plant was completed, and on January 3 of that year the apparatus was in working order. It was on December 20, 1903, however, before the first messages were sent by Marconi, from the American shores, to the Kings of England and Italy. Now there are many stations in use, and the sending of wireless messages is a matter of hourly occurrence. Most of the warships of civilized countries are equipped with wireless outfits; and the majority of sea-going vessels are enabled, by its aid, to keep in touch with land throughout their voyage, so that news from all over the world may be read by the passengers of these boats, just as they are read on land! In several instances, too, wireless message-sending has been the means of saving the crews of wrecked vessels, thus preventing loss of life.

SCIENTIFIC CONSTRUCTION.

After what has been said above regarding the construction and method of sending wireless messages, it is unnecessary to go into the subject deeply. Constant modifications and improvements are being made, so that one system is constantly being discarded and replaced by another. Some illustrative points in this connection will be of interest however.

After years of experimenting, Marconi discovered that it was easier to send messages by night than by day; and in fact messages were received at night which were hardly receivable at all by day. Why this should be so was long a puzzle; indeed it may be said to be still a puzzle, to a certain extent. Marconi himself, in writing of this, says:

"I do not think this effect [the increased range of the messages, at night] has yet been satisfactorily investigated and explained. At the time I carried out the tests, I was of the opinion that it might be due to the loss of energy at the transmitter, causing the dis-electrification of the highly charged transmitting elevated conductor under the influence of sunlight. I am now inclined to believe that the absorption of electric waves during the daytime is due to the ionization of the gaseous molecules of the air, effected by ultra violet rays, which emanate from the sun, and which absorb some of the energy of these electric waves."

Tremendous power is necessary for the sending of these wireless messages, in the development of which Nicola Tesla has played a large part. Professor Ballillie, for example, uses some fifteen thousand volts, while Professor Fessenden, in the United States Navy experimental station, has employed from twelve thousand five hundred to twenty-five thousand volts. This high voltage is not, however, generally used in communication, except for extreme distances.

At the present day, every civilized country in the world has a number of wireless stations along its coast for use in internal affairs, as well as upon its marine and war vessels, and more are constantly being installed. One of the latest and most interesting developments in this line is that of Professor Lapel, which development has become the property of the French Government. It is said that the violent emission of electric sparks at the receiving end has been entirely overcome, as well as the disturbances and interferences of the weather. Instead of the Morse Code, musical tones are employed in sending the messages. So many improvements have taken place within the past few years in wireless telegraphy that we are no longer surprised at anything, and wait with wonderment for the next developments—to see what they may be. Doubtless, it will be in the application of wireless telegraphy to various other problems and industrial inventions and improvements.

CHAPTER LX.

Some Wonders in Building and Construction.

THE STORY OF THE BRIDGE.

WHENEVER in the course of a stroll through the country we happen to come to a stream or river, we always want to get across and explore the opposite bank. This desire to cross streams or deep gorges, either for pleasure or for the convenience of commerce with the opposite side, finds its expression in the primitive rope bridges spanning the tremendous chasms of the Andes, the tropical rivers of Africa and South America, or indeed any of the wild and rugged regions inhabited by man. Our modern web-like structures of steel, so graceful in their design, present to us the final solution of the first simple desire to cross over rivers and canyons with our horses and wagons and, later, with our trains of cars laden with passengers and goods.

History is replete with the story of the bridge, and upon it the engineers, since the days of the Roman Empire, have bent their skill in design and construction. Timber bridges were no doubt the first ones to be regularly constructed after some definite plan; and these were soon followed by stone arches, many of which have fallen in decay.

A masonry arch bridge was built across the Tiber near Rome by the Censor Ælius Scaurus in the year 100 B. C., which rebuilt from time to time, is now known as the Ponte Molle. We also have interesting records of Trajan's Bridge, built across the Danube just below the Rapids of the Iron Gate in 104 A. D.; and the story of many more of these ancient structures is blended with the stirring events of which history tells us.

We have all heard of the famous London Bridge across the Thames. This was begun in 1176 by Peter of Colechurch and completed in 1209, four years after his death. This bridge therefore required thirty-three years for its construction. It was a series of stone arches, and it has become famous because of the timber houses, three stories high, that were built along it from end to end, the thoroughfare being continued through the middle of the first floors of the houses and covered by an archway. These houses are said to have been beautiful structures, and their roofs were used as promenades. They were all burned in the Great Fire of London, in 1666, and this conflagration no doubt gave the name to that widely known game that all children play called "London Bridge is falling down."

The present London Bridge, built on the site of the old one, is of recent date and was constructed by the eminent English engineer, Sir John Rennie.

CONCRETE, THE NEW BUILDING MATERIAL.

The masonry arch is seldom used nowadays and finds no place among modern structures of large span. We have, however, arches built up of a large solid mass of reinforced concrete. Reinforced concrete is a new material that is being used very much at present in building construction. We know that it is exceedingly hard to crush a piece of cement after it has hardened, but it is very much easier to pull it apart. In reinforced cement, rods of steel are imbedded in the cement or concrete, as it is called when the cement is mixed with sand and broken stones, so that the pulling apart stress or forces will be resisted by these steel rods. Therefore, reinforced concrete is very much stronger than ordinary concrete.

This reinforced concrete is used in bridges of moderate span, but of course it is employed only in places where false work or moulds can be erected to hold up the bridge until it has had time to harden.

Bridges built of steel are by far the most important of modern structures of this kind. We will define the various types into which they are divided, so that any boy who cares to study the matter a little, can easily tell them apart, and will become familiar with the principles upon which they are constructed.

THE SMALL RAILWAY BRIDGE.

Let us first consider the type of bridge known as a truss. This is most familiar along country roads spanning small streams, and is often seen on railway lines where the tracks have to cross over rivers of moderate breadth. The truss has many different forms, but the most widely used types are those shown in the plate on steel bridges. They are the Howe, Pratt, and Warren Trusses. As will be observed from the drawings, there are two ways in which a truss can be used in bridging over any particular place. The roadway can be placed on top, or, as engineers say, on the upper chord, and then it is known as a ''deck truss''; or the track or roadway can be placed on the bottom chord and carried through the center of the truss, and we have the familiar ''through truss,'' the one that is most often seen.

As we have indicated, the upper horizontal line of any truss is called the ''upper chord.'' Likewise, the lower horizontal line is called the ''lower chord.'' The short lines going up and down, and in a slanting direction, are the ''vertical'' and the ''web members'' respectively. Another thing useful to know is the fact that a truss is said to be made up of ''panels.'' That is, the parts of the truss between the vertical members are the panels. The places where the vertical and the web members join the upper and lower chords are the ''panel points.'' In large structures the panel points are very large steel pins, and the members all have holes in each end through which these pins pass. The truss is then said to be "pin connected."

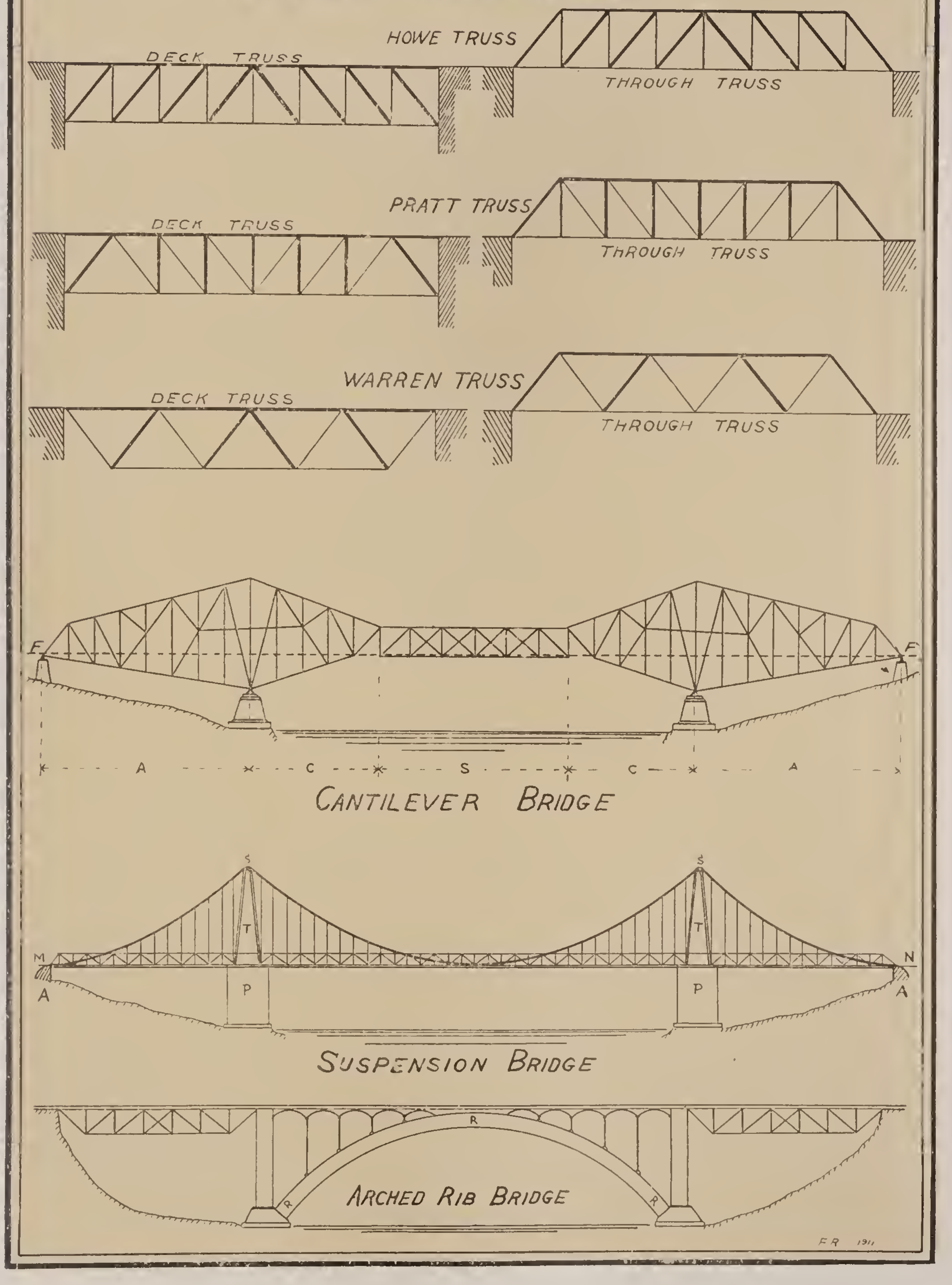
Another thing that is of great interest, and is the basis upon which all truss structures are designed, is the fact that two kinds of stress take place in all bridges. That is, some parts, or "members," as they are termed, are subjected to a pulling apart, or "tension." Other members are pushed together, or are under "compression." Still others, due to the action of the moving train, or the "live load," as it is called, are subjected to "tension" at one time, and "compression" at another.

We all know that a rope will support a pulling or tension stress, but will not resist a compressive stress, as it is not a rigid member. Therefore engineers have built these trusses so that those members shown in light lines in the drawings are especially fitted to resist pull or tension, while the members shown in heavy lines are rigid, and can resist compression without bending.

It will test the ingenuity of the average bright boy to place an imaginary weight on the trusses shown, and try to figure out the reason why certain parts are in compression and why other parts are in tension. We know that if we take a hard rubber ruler and place it between two books like a bridge, and then press down upon it, the top side of the ruler will be pressed together and the bottom side will be pulled apart. The same simple principle is employed in the truss, whether it be of fifty-feet span or five hundred and fifty—which, by the way, is about the limit for this type of bridge.

By means of analytical mathematical analysis, and what is called graphic statics, engineers are able—assuming certain weights for the bridge and the load it will carry, and certain wind forces, and, if the bridge be in the north, or the extreme south, certain values

TYPES OF STEEL BRIDGES



for snow load—to tell just how much stress each part will have to bear. Then, knowing the tensile and compressive strength of steel, they can figure out how large the different members will have to be made to make the bridge safe. This work is very complicated and can be done only after long and diligent study.

It may be well to define two terms that are often confused in the minds of people not versed in engineering language.

Stress is the force acting upon any member of a structure.

Strain is any alteration in the dimensions of the member due to excessive stress.

THE CANTILEVER BRIDGE THAT CROSSES GREAT CHASMS.

We will now consider another type of truss structure that is a distinctly modern engineering development. This is the cantilever bridge.

The cantilever bridge is nothing but a great steel balance, and is built over vast chasms or roaring torrents *without the use of any staging or falsework whatever.* The structure is founded on the main piers and is built out on either side, each part balancing the other.

The cantilever shown in the drawing is one having a single span; however, many of these structures have two and three spans built on the same principle. The parts included over the letter A are called the "anchor arms," and at the extreme ends of the bridge these anchor arms are securely fastened to the "anchor piers." The parts included over the letter C are the "cantilever arms," and that part over the letter S is the "suspended span."

The principle upon which the bridge is designed is this: The weight of the anchor arm is equal to the weight of the cantilever arm, plus one-half the weight of the suspended span. Therefore, when the bridge is finally completed, the entire structure is in equilibrium.

Should a very heavy train come on the bridge, its weight is counter-balanced by the weight of the anchor piers. The roadway, or "floor system," is carried through the structure, as shown by the dotted line.

There are, of course, many different designs embodying the cantilever principle. The Queensborough Bridge, which spans the East River at New York, is a cantilever without a suspended span. This, however, is not considered a good design. The Quebec Bridge, which collapsed during the first attempt at construction, failed because the compression members were not strong enough. This is the largest span that has been projected up to the present time for a bridge of the cantilever type. When completed, the new Quebec bridge will have a clear span of 1800 feet.

The famous Firth of Forth cantilever bridge in Scotland has two long spans of 1710 feet each. This magnificent structure has tubular compression members, which were built up from curved plates as the bridge was constructed. The cantilever is an expensive bridge to build, but where it is necessary to span streams or other obstructions with heavy railway tracks, it is the most rigid and durable type of bridge.

THE GRACEFUL SUSPENSION BRIDGE.

The suspension bridge is familiar to most of us. Those who have not had the opportunity to pass over and view one of these graceful bridges have certainly admired pictures of them in our school-books.

The suspension bridge is very simple in principle, and fortunately it presents no very great difficulties for the designer. It consists of two or more "towers" (T in the drawing), resting upon "piers" (P) on either shore and fitted with rounded tops, or "saddles" (S, S), over which the "cables" pass. These cables are made fast to heavy "anchorages" on either shore (shown by A, A, in the drawing). The roadway is carried on a long "truss" (M, N), which is supported by vertical "suspender rods" coming down from the cables. The truss is called a "stiffening truss"; it is not designed to carry the load, but is strong enough to spread it out over a number of the suspender rods, and also because of its lateral bracing to stiffen the bridge against "wind stresses."

One of the most notable examples of the suspension bridge is that known as the Brooklyn Bridge, spanning the East River in lower New York. This is one of the first examples of a stiffened suspension bridge. Two other suspension bridges now span the East River, the Williamsburg Bridge and the Manhattan Bridge. Both of these bridges have steel towers. Stiffened suspension bridges with spans of nearly three thousand feet have been designed to cross the Hudson River at New York.

Another type of bridge often seen is the arched rib bridge. The first bridge of this type of any consequence was the Eads arched-rib bridge structure across the Mississippi River at St. Louis. After this bridge was built many more similar structures were erected.

The arched-rib bridge, as shown in the drawing, consists of an *arched rib* of steel, of either web or lattice-work construction, upon the haunches of which are placed pillars to support the roadway. The arched rib may take any number of forms and can be easily recognized. It makes a beautiful, symmetrical bridge. The Washington Bridge, over the Harlem River in New York, is a notable example.

Besides the bridges mentioned above, we have numerous types of the movable bridge, of which the common "swing bridge" is perhaps the most familiar. These bridges find their greatest use in carrying streets and railroad tracks over canals and small streams. The "jackknife," or bascule, bridge is another structure that is being used in such places to a great extent. The Tower Bridge over the Thames at

London is a bascule bridge. "Lift bridges" have been built. A notable example is the famous Halsted Street Bridge over the Chicago River in that city.

"Viaducts" come under the heading of bridge structures in engineering work, and usually consist of a series of steel or masonry towers connected by truss structures.

The subject of bridges is an interesting one when not overburdened with a mass of dry mathematical formulæ. To project and design a long span bridge is a great achievement in engineering. The design for long cantilever structures is far from standard, and we shall see great advances in this art as the years go by.

UNDER—WATER TUNNELING.

The art of tunneling under river beds is a very recent one, if we compare it with other engineering works in point of time. Modern methods employ the use of "air pressure," and this important and interesting principle had better be explained if we wish to understand the true meaning of under-water tunneling.

If we take a common glass tumbler and place it bottom up in a basin of water, we shall observe that no water will enter the glass as it is thrust below the surface. This is due to the air in the glass. Our study of physics will tell us that no two things can occupy the same space at the same time, therefore we see that so long as the glass is full of air the water will not enter it. In tunneling work we make use of a huge circular steel shell, open at one end, much the same as a glass, and closed at the other. At the closed end is placed a chamber with two doors, one opening into the shell, and the other opening into the air. This chamber is called an "air lock," and it allows men and materials to be taken from or entered into the "working chamber" of the shell without allowing all the air to escape from the inside when this air is under pressure, as it always is when the circular steel shell, or the "shield," as it is called by the engineers, is under ground, or beneath the surface of the water in the river.

HOW THE GREAT HUDSON RIVER TUNNELS WERE BUILT.

The shield begins its work on the shore of the river beneath which it is intended to tunnel. Men enter the working chamber of the shield and dig away the earth and rock ahead of it. As soon as enough of this material has been dug away, "hydraulic jacks" are placed against the closed or rear end of the shield, and it is then pushed bodily into the space dug out by the men. An iron ring is built up behind the shield in the place just previously occupied by it before it was pushed ahead. This operation is repeated over and over again. As the shield gets deeper under the river, the ground water, being farther down, is under greater and greater pressure, and consequently the air in the shield must be put under greater pressure in order to keep out this water. This is done by means of air pumps, and the workmen, or "sand hogs," as they are called, must be accustomed to withstand this increased air pressure. Any one who has gone through one of the tubes beneath the East River or the Hudson has noticed the ribbed inside surface of the tunnels. This is due to the succession of cast-iron rings of which the tunnel is built up, as the great shield is pushed ahead by the hydraulic jacks. As fast as the men in the shield pass out the excavated material from the inside of the working chamber, it is carried through the completed portion of the tunnel to the rear of the shield.

EXCITING MOMENT FOR THE UNDERGROUND WORKERS.

Tunneling after this fashion is begun on both shores, and if the surveys have been accurate, and the shield has been directed truly by the engineers in charge of the work, some day the "sand hogs" in one of the shields will hear the blasting or the sound of picks in the wall of rock or mud ahead of them; and they know that it is then only a matter of a few more hours of hard work before the two shields will come together and the cutting of the tunnel will be completed.

HOW SKY-SCRAPERS ARE BEGUN.

In tunneling under rivers, the shield is placed in a nearly horizontal position, and the movement is lateral or in a direction nearly parallel to the surface. The same principle of work is employed in sinking shafts for the foundations of huge modern "sky-scrapers." Here the shield is called a "caisson"; it goes straight down, and as the earth and rock is dug away from beneath it the caisson sinks from the weight of the concrete that is loaded on top. When bed rock has been reached, the men withdraw from the working chamber and fill it up with concrete; they also fill up the central working shaft through which they passed up the material from below, and we have a solid monolithic column of concrete rising from bed rock to the bearing girders of the building.

Men working in the shields or caissons under excessive air pressure can remain in the working chambers only a few hours. Only those who are physically strong and of good heart action can go down into these places. Sometimes, when the workmen are in a hurry to get home from their tasks, they leave the air chambers too quickly, and do not allow the pressure on their bodies to equalize by remaining for some time in the entering chambers, or "air locks," where the pressure is gradually lowered. When they do not take this precaution, they are often attacked by an ailment called the "bends." This painful attack doubles them up in violent contortions, and unless the sufferer is at once placed under air pressure again it is liable to prove fatal. All boys who become engineers and take up tunneling work should remember this and never leave the air locks too soon, but should remain long enough to give the blood circulation time to adjust itself to normal conditions.

TUNNELING THROUGH MOUNTAINS; FROZEN QUICKSANDS.

Tunneling through mountains, as in railway work, or under ground, where the tunnel is above the "water table," as the water level in the ground is called, presents no features of extreme difficulty. In such works as the St. Gothard Tunnel in Switzerland, the work depends for its distinction upon the great magnitude of the undertaking. Where the rock is hard and the distance to be tunneled long, the work may be expensive, but it is done easily according to modern engineering methods.

A very interesting development in recent tunneling works through quicksands has called into play the use of a freezing apparatus. Ammonia pipes are sunk into the sand and the whole mass is frozen solid by means of refrigerating machinery. The frozen sand is then blasted out and the structure is built while the surrounding walls of quicksand remain frozen.

Soon after the beginning of the Christian era, canals were introduced and were gradually extended throughout Europe. The origin of the lock, that simple device which enables us to lift our vessels from a lower to a higher level, or to let them down from a higher to a lower level, has been lost in the mists of antiquity. Some claim that Italian engineers were the first to make use of a lock; but others contend that the lock was used in the canals of Holland nearly a hundred years before the Italians employed it in their works.

AN INGENIOUS BUT SIMPLE DEVICE.

The lock—to define this necessary adjunct to a canal before going further—consists, in its simplest form, of a compartment in the line of the canal separating two sections of the canal having different levels. Say a canal-boat or vessel in the lower section of the canal wishes to enter a higher section. The gates of the lock leading to the upper section are closed. The lower gates are opened and the water in the lock is at the same level as that in the lower section. The vessel then enters the lock, and the lower gates are closed. Then the water from the higher level is allowed gradually to enter the lock until the water in the lock is at the same level as the water in the upper section of the canal. When this is accomplished, the gates to the upper section are opened, and the vessel continues on its journey along the upper section. By a series of such locks a vessel can be lifted to any necessary or desired elevation. It will be readily noted that the raising or lowering of a boat by means of locks calls for the expenditure of a certain amount of water every time a lock is filled and emptied. Where there is a sufficient supply of water in the upper sections of the canal, this is a matter of no importance.

Locks are a source of some delay in the navigation of any canal, but on the other hand they alone make a canal possible in a great many places. We have heard much about the discussion as to whether the Panama Canal should have locks or be a sea-level canal—that is, one without locks, dug straight through from ocean to ocean. For various reasons the Government has decided to build a lock canal. This will mean the construction of great dams, and a series of locks of very large dimensions. It also saves a great deal of excavation that would otherwise have to be done in order to make the sea-level type possible.

THE GREATEST CANAL IN THE WORLD.

In the work on the Panama Canal, engineering science met every known problem of canal construction, and in addition, several that were unique. The difficulties of great locks, immense cuts, fills, spillways, swamps, quicksands, and slides, were but exaggerated examples of similar difficulties met in the building of any canal, but at Panama, the effect of the climate on white men, the deadly diseases like yellow fever, the entire care of an army of workers, and, above all, the extraordinary rainfall of a tropical region, had to be provided for. That the problems presented were successfully provided for, reflects the greatest possible credit upon the American engineers in charge of the work. All who read about the canal will find frequent references to the Gatun Dam, and it is worth while to remember that this stupendous work, the greatest of its kind, was necessitated because the Charges River, which is depended upon to supply water for the higher level of the canal, goes on a rampage after a rainfall, and rises with a rapidity and violence most of us cannot realize. This great dam holds the water for use when the water is needed, and the uniqueness of its planning is that it can at the same time dispose of any excessive rainfall without risk of disaster. It allows to flow harmlessly away much more water than the river has ever been known to bring down in the heaviest freshet.

Canal construction is not much different now from what it was when the first ditches were dug and water was turned into them. The only difference is in the methods employed in digging. Formerly excavation was done laboriously by means of shovels, and perhaps by the use of some crude form of crane and bucket. Now we have great steam shovels, and monster cantilever cranes stretching their long necks out over a ditch, dropping down a great bucket shaped like a clam shell, and bringing up a wagon-load of dirt at a time. It is by the use of such machinery as this that the enormous excavation for the Panama Canal is possible, the figures of which are so great, they fail to convey much meaning, and need not be given. A better comprehension of the magnitude of the whole work is gained from the statement that more than 45,000 men are at work on the enterprise.

PART VI.

THINGS WHICH MINISTER TO MAN'S COMFORT AND PLEASURE.

CHAPTER LXI.

Modern Musical Instruments.

ANTIQUITY OF MUSICAL INSTRUMENTS.

WHATEVER was the path of invention that led ancient man to mold or make the first musical instruments—and this is one of the mooted questions in the history of music—all authorities admit their great antiquity. Not only did every ancient people known to history make and use musical instruments, but many prehistoric tribes as well had varieties of them. This fact is shown by the recent discovery of an Egyptian flute, which scientists believe to be at least five thousand years old. Numerous other archæological discoveries of musical instruments, made of stone and of animals' bones, would seem to place their origin even farther back. As every subsequent discovery is just as likely to continue this shifting process, wise men will not pretend to know exactly when musical instruments originated. A general belief in their wonderful remoteness is all that our present state of knowledge seems to warrant.

SOME OF THEIR QUEER USES.

Primitive man does not use musical instruments as we do, to afford pleasure, but always for some practical purpose. Thus, the Kaffirs in Africa employ theirs merely to call their cattle; the Caribs, in South America, to announce their home-coming when preparations for their reception must immediately be made; the Iroquois Indian, to entice his lady-love from her wigwam; the Keres, in New Mexico, to keep time while at work; the negroes in Africa as a means of communication from great distances, etc. Of course, as with us, musical instruments are played to accompany dancing, marching, and various religious ceremonies. In general, however, uncivilized peoples know nothing—how could they?—of the higher uses of musical instruments to delight the ear or to engage the imagination. Whenever savages are greatly affected at the sound of certain musical instruments, it is due to the definite meaning that such sound conveys to their minds. The sound of a horn frequently spells war to the savage; the beating of a drum is known to inspire religious awe among the Ashantis of Guinea (West Africa); and so on through the range of sound. In short, primitive peoples have no art for art's sake.

CLASSIFICATION OF MUSICAL INSTRUMENTS.

Whatever be the purpose of using musical instruments now or in times past, and however great be their number, they are reducible to three general kinds, according to the method by which they are caused to produce sound. The performer may produce sound by blowing into instruments—the flute, the horn, etc.—and the name "wind-instruments" covers all this class. Or he may play upon the strings of instruments—such as the violin and the harp—by means of a bow or otherwise, and all instruments so played are known as "stringed instruments." Again, the performer may produce sound upon musical instruments—such as the drum, the triangle, and the tambourine—by striking them in various ways, and "instruments of percussion" is the name applied to this class. Finally, we have the mechanical musical instruments. We shall now consider each of these classes in detail, taking up the principal musical instruments composing a given class to see their general nature, their peculiar tone, and their special place in the modern orchestra.

WIND-INSTRUMENTS.

Wind-instruments are musical instruments in which currents of air produce the sound. As such instruments are usually made of either wood or brass, it is customary to subdivide them into wind-instruments of wood (also called "the wood-wind") and wind-instruments of brass (known as "the brass," for short). There are, besides, wind-instruments played by a keyboard (such as the organ).

WIND-INSTRUMENTS OF WOOD.

The wood-wind, although second in rank today as orchestral or solo instruments, were the first musical instruments used by primitive man. This large group includes flutes, clarinets, oboes, piccolos, bassoons, bass-clarinets, and English horns.

The flute is by far the oldest musical instrument. We have an Egyptian specimen believed to be more than five thousand years old. Perhaps the most remarkable fact about primitive flute-playing is the common custom of blowing this instrument by means of the nostrils—a feat which, despite modern virtuosity, never is attempted by civilized man.

Nowadays, with less effort, more satisfying melodies are being played on the flute. As a solo instrument it is frequently heard in beautiful compositions, written specially for its range of tone; as an orchestral instrument it never can be dispensed with. Its tone is very characteristic—soft and sweet, on the one hand, clear and penetrating on the other. The flute is the liveliest instrument in the entire group of wind-instruments. But, despite its agility, it is capable of a good deal of expression in the hands of real artists.

The clarinet is an instrument capable of much more expression, when played with skill and judgment, than perhaps any other member of the wood-wind family. As known today, the clarinet was invented practically in 1690, although it doubtless had earlier prototypes. This instrument also serves as either a solo or an orchestral performer, having a rich, full, and clear tone. It permits the most perfect scale of gradations in the power of tones. Its highest notes are too piercing, but softer playing upon the clarinet is very pleasing. Because of its extensive range, this instrument occupies a very important place in the modern orchestra.

There are various kinds of clarinets, intended to increase still further their orchestral usefulness by greater variety of tone. But upon these we cannot dilate.

The oboe, like the flute, has a very ancient history, but its predecessors bore different names. While the flute is played by means of a circular aperture on the side of the instrument, the oboe represents ''the double-reed'' family—instruments played by blowing onto reeds. It differs from the flute in shape also, being larger at its lower end. The range of tones possible on the oboe is almost as great as that of the clarinet. The best tones of the oboe have a real pastoral quality, suggesting nothing so much as the shepherd's pipe. This instrument, therefore, almost invariably plays such passages in the score as are distinctly pastoral in character; and no one who ever has listened to the sweet and tender music flowing from an oboe played by an accomplished musician will be likely to mistake its sound for that of another instrument. Being essentially a lyric instrument of melancholic suggestiveness, the oboe is not well suited to either gay or tragic parts. One distinct feature of the oboe is the slight amount of breath required to play it; and the oboe player, we are told, is frequently glad "to rest his lungs from too little work." There must be many and frequent pauses in music intended for this player to enable him to exhale. This is one reason why little solo music has been written for this instrument. As an orchestral instrument, however, the oboe has become a great favorite with composers. The oboe, too, enjoys the enviable distinction of giving the pitch to the orchestra, and should you reach the concert hall in good time you may hear the other instruments carefully tuning up to their leader's dominant notes.

The piccolo is really a special kind of flute, and, in all but the largest orchestras, is played by one of the regular flutists. Being the shrillest tone producer in the orchestra, it is well used in passages suggestive of merriment and diabolical sportiveness. The piccolo has therefore won the name, "the imp of the orchestra." There is no mistaking the quick, snappy tone of the instrument, which can be heard above the entire body of orchestral sound. For this reason, one piccolo is all that is usually required even in an orchestra of a hundred pieces. It must not be understood, however, that mere noise is the only distinction of this instrument. Many of our best composers have assigned beautiful soft passages to the piccolo.

The bassoon is a bass oboe. It has been known since 1540, the date of its discovery, but probably it existed much earlier in Oriental countries. You will have no difficulty in recognizing this peculiarly shaped instrument: a tapering tube, doubled upon itself, with a brass crook to hold the mouthpiece. It is certainly not a very graceful instrument, and its sound is as peculiar as its appearance. The bassoon can produce a great variety of effects. Like the oboe, to which type of instrument it belongs, the bassoon is capable of pastoral tones in its upper register. Some of its notes are highly suggestive of a cry of grief. However, despite this usually grave and solemn nature of the bassoon, capable of expressing extreme human agony, some of its tones lend themselves to grotesque effects. Because many composers have used the bassoon in the latter capacity, it has been called the clown of the orchestra.

That the bassoon can be as disagreeable as humorous is impressively shown by the following incident: A famous German conductor (Von Bülow, by name), found during a rehearsal that some insistent ladies had stealthily taken seats in the hall. Seeing that they intended to stay for the rehearsal, the conductor, turning to his orchestra, said, ''Gentlemen, we will take the bassoon part first.'' After conducting the bassoons through a long series of grunts, the ingenious conductor found to his great relief that the unwelcome audience had deserted, the charge of ''the bassoon brigade'' having frustrated their purpose.

The bass-clarinet is, as the name implies, a clarinet of deeper tone. It differs in form from the ordinary clarinet in having a crook for its mouthpiece and a wide bell-shaped terminal opening, doubled on itself. Its lower tones are rich and sonorous, but its higher notes are less pleasant and hence are seldom used. As a solo instrument the bass-clarinet is very dignified, and was first used in an eloquent monologue by Meyerbeer (in his Opera ''Les Huguenots''). Since that time, other great composers, Wagner especially, have written many melodious passages for this instrument.

The English horn, contrary to its misleading name, is not a brass instrument at all—we should not be considering it under ''wind-instruments of wood,'' if it were. It received its name because it developed out of an English instrument called the hornpipe (consisting of a tube, a reed mouthpiece, and a bell of horn).

It must certainly have been known in Chaucer's time (the fourteenth century), since this early English poet refers to this instrument in one of his poems. The tone of the English horn resembles that of the oboe, though it is somewhat more expressive and melancholy.

WIND-INSTRUMENTS OF BRASS.

The wood-wind instruments just described depend upon the vibration of the air itself for the nature of their tone. The instruments we are now to study—the brass division of wind-instruments—get the nature of their tone from the vibrations of the lips of the performer, pressed (usually against a cup-shaped mouthpiece) with differing degrees of intensity. Other differences between the brass and the wood contingents of wind instruments exist, but these are somewhat too technical for non-musical readers.

The brass choir consists of horns, trumpets, cornets, trombones, and tubas. As the first set of this group has undoubtedly been known from earliest times, the brass wind-instruments vie with the wood-wind in antiquity. In ancient Greece and Rome both horns and trumpets were much used in hunting, and at no time since were they ever unknown. It is doubtful, however, whether any other instruments called musical ever were put to so many unmusical uses as those that are made of brass and played by the mouth.

The horn consisted originally of merely a tube, and it was this simple instrument that savages used in war and hunting. Gradually, however, the horn became more and more curved, so that it could be hung about one's body. Its present form is but a further modification of the earlier curvature. Made originally of bone, ivory, or even wood, the present orchestral horn is brass throughout. The "French horn" is the common name by which this instrument is known generally today. For orchestral purposes it was not introduced before the middle of the eighteenth century, and, strangely enough, it had to overcome considerably opposition even then. Those who have heard the noble horn in the hands of good players—heard its smooth, charming, and sombre tone—can only wonder why this instrument was at first considered coarse and vulgar. Nowadays, however, there is no better musical treat than hearing a masterful French-horn player. Anyone whose good fortune it has been to hear such famous horn passages as Beethoven, Schubert, Weber, Brahms, Mendelssohn and Wagner have written, never can forget the beautiful quality of tone characteristic of the horn.

The trumpet is another of the oldest musical instruments. So old a country as China ascribes great antiquity to the trumpet. It was known in Egypt and must have been familiar to the Hebrew prophets, or they could not have held this innocent instrument responsible for the fall of the ancient walls of Jericho. From the accounts of the Trojan war, we know that Greece had trumpets very early, as had also Rome. During the Middle Ages the trumpet was a favorite with Knights and Kings. There was even an orchestra composed largely of trumpets of various kinds. Indeed, so important did the trumpeters become at one time that a trumpeters' guild, perhaps the oldest musical union, was organized in order to perpetuate a high musical standard among its members.

This fine instrument has a rich and brilliant tone, and is sometimes called the soprano of the brass division. Being difficult to play well, good trumpeters are rather scarce in modern days. Hence, in all but the largest orchestras and finest brass bands, the cornet, the trumpet's nearest relative, takes its place.

The cornet, however, is but a poor substitute for the trumpet. Its tone is not so full and fine as that of the latter, and it usually sounds rather ''brassy'' in comparison with that instrument. It takes a very skilled player to overcome or subdue its blatant quality. The single great difference between the trumpet and the cornet, so far as construction is concerned, is found in the mouthpiece. It is to this difference that some ascribe the ‘‘brassiness’’ of the cornet. It is capable, however, of considerable fluency and great rapidity in execution, and this accounts for its popularity as a solo instrument. Cornets and trumpets are generally used—or, rather are intended to be used—in pairs in the modern orchestra. The various kinds of cornets we need not describe.

The trombone was well known in the sixteenth century—probably very much earlier—though it did not enter the orchestra before the nineteenth. Like the trumpet we have just been speaking of, the trombone—and the name in Italian means a large trumpet—is a long brass tube that is cylindrical save for its bell and mouthpiece, much wider than that of either the trumpet or the horn. Two short curves connect its three parallel lines, and one of these curves forms the slide by means of which variations in tone are produced. You have surely seen trombone players move this slide in and out, as if they were ‘‘pumping sound.’’ It is the use of the slide that renders the trombone so easy of modulation and yet so difficult to play well. There are, however, trombones without slides, but these are never so perfect in tone as the slide variety.

The characteristic tone of the trombone is grave and majestic, but good performers are just as rare here as in the case of trumpets. Extremely fine effects are possible by either changing the pressure of blowing or by modulating the slide of the instrument. Quick passages are not effective musically, and yet concertos for the trombone are not unknown. It is, however, as an orchestral instrument that the trombone is invaluable. The trombone is particularly suited to depict heroic emotions by its deep, powerful, poetic notes. It is equally effective in suggesting religious or martial moods, soothing or threatening airs. All great composers obtain beautiful effects upon the trombone, and Mendelssohn's admiration for it was so great that he considered its use too sacred on ordinary occasions.

The tuba has been characterized as "a deep-toned brass instrument of double-bass quality." It has a mouthpiece similar to that of the trombone, and is equipped with pistons. Its range of sound is very great, and that commends it to modern orchestral composers. Wagner, in his music dramas, shows a particular fondness for the tuba—in one place calling for as many as five of the kind. Though unable to produce the smooth and sombre notes possible on the trombone, a good tuba player need not necessarily be harsh. Its tone, once distinguished, can never afterwards be mistaken; it is so characteristic.

KEYBOARD WIND-INSTRUMENTS.

In this type of musical instrument, of which the organ is the chief representative, the keyboard is the means of operation. The history of the keyboard cannot be entered into here, except to note that its essential mechanical principle must have been known in antiquity. Certainly by the sixteenth century the keyboard, in all essentials the one used today on organs and pianos, had become fully established. Its original application was to the organ, but by the end of the seventeenth century its use was extended to a number of musical instruments, including the earliest form of the modern piano. It is not easy briefly to explain the operation of the keyboard to produce musical sound, but all who would understand it need only look into any modern piano. Perhaps the relation of the perfection of the keyboard to musical progress is not self-evident, but its influence upon the latter has been enormous.

The organ has been known since the thirteenth century, and its development has been largely connected with the rise and development of church music. It was in church worship that the largest organs have usually been employed, especially in the three centuries immediately preceding our own. Naturally, too, most organ music has hitherto been of a sacred character. Even the greatest composer of organ music (Bach, in the eighteenth century), wrote most of his work for church performance. Recently, however, organ music of a secular character has been successfully written.

Organ-making up to the fifteenth century lay entirely in the hands of monks, but after that it became a regular trade. As large organs could not, when made, be transported in those days, such instruments had to be built on the spot. Necessarily, organ-makers traveled from place to place, according to the demand for their services. As a very complex instrument, the organ has undergone continual development since its introduction. Today it seems as perfect a musical instrument as is known. With the organ we reach the first musical instrument in our study—the piano will be another—which may be called self-sufficient. None of the instruments we have discussed so far can play melody and accompaniment at the same time. The organ, however, can not only do this, but even embodies the effects of all the orchestral instruments. Therefore it can play the most complex as well as the simplest musical scores as if it were an orchestra. Indeed, whenever an orchestra is not available for the performance of orchestral music, no instrument can replace the organ for this purpose. But, like all other musical instruments, the organ is at its best in music composed for it especially, of which there is a great abundance.

As music, before the advent of the organ, had been chiefly vocal, and as the organ was the greatest single factor that served to popularize instrumental music, the influence of this instrument upon the course of general musical development cannot be overestimated.

BOWED STRING INSTRUMENTS.

Only four kinds of instruments—violins, violas, violoncellos, and double-basses—compose this group, in orchestral parlance called simply "the strings." Yet, the string choir is far more important than either the wood-wind or the brass. Varied and great as are the musical possibilities of the latter, they cannot equal in range and power of expression the possibilities of the strings. Whoever has heard a good string quartet—and those who have not should hasten to fill this gap in their musical experience—knows what delightful musical effects can be produced by just four string instruments. No wonder, therefore, that the strings form the basis of our modern orchestra—certainly not if we remember also that string instruments, being easier to play, can be relied upon for more sustained efforts than wind instruments.

The violin is the oldest and most important member of the group we are now considering. The history of "the queen of the orchestra" has not yet been clearly made out. It may have originated in very primitive times among the Arabs, who had something resembling a violin called "the rehal;" among early Welshmen, who had another possible prototype of the violin; or among the Hindus, whose "ravonastron" also suggests remote kinship to the violin. But whatever its ancestry, the violin was well known in mediæval times, being generally used by the troubadours in the form of a fiddle (a name we still use sometimes). From the mediæval fiddle to the viol, and from that to the modern violin, seems to have been the natural evolution of the instrument.

At any rate, this evolution of the violin was much furthered by the work of geniuses like Stradivari and Guarneri, famous violin-makers who lived in the seventeenth and eighteenth centuries and whose stamp upon violins render these instruments precious even today. You have surely seen or heard mention of "a Stradivarius" or "a Guarnerius," without knowing what they were or what made them bring such fabulous prices. Now you will understand.

The perfect violin is the result of much technical study and numerous delicate adjustments. The genius of the great violin makers lay in patiently mastering every detail and conquering every problem involved. The multitudinous niceties of the art include a thousand-and-one matters that are never appreciated by anyone who has not seen a good violin built up out of sixty or more small pieces. Few indeed realize how much of art and science violin-making involves. But the story of the violin, extremely interesting though it be, space will not permit us to tell here.

About the musical qualities of this instrument little need be said. Who has not heard the violin express the deepest emotion, the most masculine mood, the tenderest feeling? It can sob or twitter, paint pathos or suggest the wildest merriment. Every shade of tone-color, every kind of musical effect, is known to the violin. In the hands of a master, what is there that the violin cannot do? While the most satisfying effects result from a large body of violins playing together (when the combined volume of tone is rich, deep, and clear), yet to appreciate the technical possibilities of the violin as a solo instrument one should hear some modern concerto for violin and orchestra (such as Beethoven, Mendelssohn, Brahms, Bruch, Saint-Saëns, and others have written) played by a mature artist and a good orchestra.

The viola is the instrument most closely related to the violin. Indeed, it is so similar to the latter that untrained observers cannot tell their difference. The viola is a fifth larger in size and has heavier strings than the violin. Otherwise, however, the two are exactly alike. Naturally, there is also great similarity in tone—another reason why the average concert-goer does not know the nature of the viola. Nearly all technical effects characteristic of the violin are possible with the viola. Yet composers did not avail themselves of this beautiful instrument before the last century, though the great Mozart (who lived in the eighteenth century) attempted to lift it out of obscurity by composing a concerto for viola and violin. Recent composers have not only raised the viola to greater rank as an orchestral instrument, but have found its tone so individual that no other instrument can replace it. The lowest notes have a certain sepulchral and bewitching character, while the middle register possesses such peculiar pathos and sweetness as cannot even be imitated by other instruments. The viola is today an indispensable member of every string quartet and every good orchestra.

The violoncello is perhaps the best known of all string instruments after the violin. Hence we need hardly describe it. You have all seen that, unlike violin or viola, this instrument is made to rest on the floor in playing. This is done simply because its size compels it. The general scope of the violoncello is even larger than that of the violin. It, too, can be made to express all emotions, like the violin, but its tone is deeper and more masculine than that of the latter. Owing to the greater compass and very much thicker strings of the 'cello (as the violoncello is commonly called), good execution upon this instrument is even harder to attain than in the case of the violin. Yet, the violoncello vies with the latter as a solo instrument. Of course, it is not expected to display such wonderful agility as the violin, but its expressiveness is even greater. In quartets the 'cello usually takes the bass part, while leading melody is not infrequently assigned to it in orchestral compositions.

‘‘Nothing is more voluptuously melancholy or more suited to the utterance of tender, languishing themes,’’ says a great French composer, ‘‘than a mass of violoncellos playing in unison on their first strings.’’

The double-bass, the last bowed string instrument we shall consider, needs but a word. Its size and tone are so impressive that all but the blind may see and all but the deaf may hear it. It has little value as a solo instrument, for virtuoso playing upon it suggests the ‘‘stunts’’ of an elephant. As an orchestral instrument the double-bass (known also as ‘‘the contrabass’’) is most important, since it supports the complex body of orchestral sound. In this respect it is the ’cello of the orchestra, performing for the latter the same function as the violoncello performs for the string quartet—producing the fundamental bass, the background, as it were, of orchestral painting.

The characteristic tone-color of the double-bass is heavy, gruff, and ponderous. Some modern composers, however, have learned to make good use of this quality in melodious passages. Its huge size, which has won the name ‘‘bull fiddle’’ for this orchestral elephant, made possible the giving of trios upon this instrument. In old England, where this custom prevailed, a boy would be concealed in the body of the double-bass to sing, while the player added his own voice to that of the boy’s. Thus resulted the invisible trios.

KEYBOARD STRING INSTRUMENTS.

In the organ we have already come upon a wind-instrument played by means of a keyboard. We are now to consider string instruments similarly operated. Although today but one important instrument of this type survives—the piano—there were throughout the eighteenth century two other keyboard string instruments—the clavichord and the harpsichord—which were very generally used. The exact history of these two instruments has not yet been ascertained. Both were known as early as the fourteenth century, however, and were developed along with the organ till the seventeenth century. Then their manufacture became a separate art in the hands of a certain family (the Ruckers, of Antwerp), which has stamped its name forever upon these instruments. Later, however, Paris and London became famous centers of their manufacture. The manufacture of both clavichords and harpsichords ceased with the close of the eighteenth century, though they were used long afterward—one even very recently (in 1909).

The clavichord, so far as the keyboard was concerned, resembled the more modern piano very closely. Its essential mechanical distinction was the manner of stringing and sounding the instrument, but this is too technical a matter to explain here. The tone of the clavichord, compared to that of the piano at its best, was thin and metallic. It lacked power, and therefore never could produce the sonorous tone necessary in concert halls. But in expressiveness this instrument is said to have rivaled the piano. It was this ''sympathetic tonality'' that won for the clavichord such warm admiration of the great Bach, Haydn, Mozart, and Beethoven.

The harpsichord was really a keyboard zither. Its tone was powerful, however, owing to the peculiar method by which the strings were snapped. But for this very reason notes of softer character lost in sonority, and ''pianissimo'' could not be reached at all. As the strings varied in length with the pitch, the form of the harpsichord became triangular or wing-shaped (somewhat like our grand pianos), and was very elaborately ornamented. Unlike the clavichord, the harpsichord was well suited for concert or music hall, and stood all the demands made upon the modern piano in theaters and elsewhere.

The piano, the greatest of the keyboard string instruments, may be called the direct descendant of the clavichord and harpsichord, since its perfection grew out of the various experiments connected with its two predecessors. Indeed, the earliest models of the piano resembled the harpsichord in shape. Thus the ''grand'' was the first type of piano made. After 1760 the ''square'' piano, modeled after the clavichord, came into use, with our present ''upright'' to follow later.

Students of primitive musical instruments claim a very remote origin for the piano, believing the marimba, one of the most characteristic musical instruments of savage peoples, to be the earliest kind of piano. In support of this belief, it is pointed out that, though the resemblance in construction is very slight, the similarity of tone is considerable. But this may be mere hypothesis (scientific guesswork). At any rate, so long as the doctors disagree, we ordinary mortals are entitled to no opinion on the subject, interesting as it may be to the antiquarian.

Certain it is that the piano as we now have it dates from early in the eighteenth century, one Cristofori of Padua having produced the first specimen somewhere about 1710 (which may still be seen in the Metropolitan Museum of Art, New York). It was not, however, till the close of that century that the numerous imperfections of the piano were sufficiently overcome. Especially important—we might say almost revolutionary—in the line of piano inventions was the damper pedal (introduced about 1780). This mechanism, you know, enables the piano player to modulate the volume of sound, making the music soft or loud at will. Other great improvements followed—such as the introduction of a metal frame, the use of the finest steel-wire strings, and almost perfect action—during the nineteenth century. While most assuredly the end is not yet, the piano is universally regarded today as the keyboard string instrument *par excellence.*

We have already referred to the piano as one of the two self-sufficient musical instruments, the organ being the other. Piano recitals are so common these days that no one need be told what this instrument can do. In the hands of a master, what can it not do? The modern development of piano technic, made possible by the gradual perfection of the instrument itself, is one of the great wonders in the history of music. The names of piano virtuosos, such as Chopin, Liszt, and Rubenstein, and piano composers, such as Beethoven, Schumann, and Mendelssohn, it would take pages to mention. While not regularly an orchestral instrument, many compositions exist for the piano and orchestra. It is in such concertos that the orchestral possibilities of the piano are made clear by mature pianists. Moreover, as a member of a string quartet or quintet, the tone of the piano blends equally well with the rest of the set. With its universal uses in the home everyone is fairly familiar, now that there is hardly a home without a piano.

PLUCKED STRING INSTRUMENTS.

The harp is at once the most important and the most ancient plucked string instrument. Go back as far as we will, there is no people too ancient to have a harp of some kind. The early Egyptians, the Hebrews, the Greeks, the Britons—all employed harps. The Irish are said to have originated it, and perhaps the present form of the harp did originate with them. But there are clear evidences of a much more ancient beginning of this instrument—among the Assyrians, an Eastern people older than the Egyptians. The modern harp was not perfected, however, before the last century (about 1810), when Sebastian Erard perfected its pedal-action and gave it the form that remains a model to the present day. As everyone has seen this graceful instrument, no description of it need be attempted. The numerous pedals attached to the harp enable its player to vary its volume of sound pretty much as do the pedals of the piano. In fact, most effects characteristic of the piano can be produced on the modern harp—some even better.

The tone of the harp—and he who has not heard it is to be pitied—is the richest and fullest possible on any plucked instrument. To say it is celestial may not give a definite idea of its real beauty, but that is the very quality its tone suggests. As a solo instrument the harp is rarely heard in modern days, but as an accompanying instrument to vocal music it has no superior.

In view of its great musical value, it is curious to note that great composers have so long neglected the harp as an orchestral instrument. Even the most prolific of them, Beethoven, called for a harp only in one minor composition. Today, however, every first-class orchestra includes a harp. What a full orchestra of harpists would sound like, one can only wonder.

INSTRUMENTS OF PERCUSSION.

All the musical instruments so far considered may be employed to produce melody. Not so with percussive instruments, which are used merely to increase the musical effect—to spice the music, as it were. This class of instruments includes bass-drums, kettle-drums, cymbals, zylophones, tamborines, triangles, and bells. Each of these has its peculiar uses in the modern orchestra, and the more ‘‘spicy’’ the music performed the more of them are employed. Space will permit us to consider only three percussive instruments—drums, bells, and kettle-drums.

The drum is the most important instrument among savage races. But it is no musical ends that the drum serves with primitive peoples. Exactly as flutes, whistles, and pipes of all kinds aid in gathering cattle, hunters, or warriors, so drums are used for practical purposes. Every African tribe has its own drum-code for communication. The present use of the drum in band and orchestra calls for no explanation. We have all heard it—perhaps too much of it. Beethoven was the first to recognize the artistic possibilities of the drum. When drumming is used to accompany marching or in sounding military signals, we should remember that this is the survival of primitive uses of the drum.

The bell was a kind of rattle in early times. But savage races seem to have learned the use of bells as musical instruments. Someone reports that a band of twelve bells heard among a certain tribe in Africa sounded from a distance like a string orchestra. Tourists who have traveled in China and Japan invariably wonder at the soft, musical notes produced by bells in temples and elsewhere in those countries. Into the modern orchestra bells were first introduced for dramatic purposes, but are now employed frequently to lend color to certain music.

The kettle-drum is the only drum which can be tuned to sound certain notes, and this makes it the most important percussive instrument in the orchestra. The older composers used kettle-drums merely to accentuate the rhythm, but since Beethoven more important effects came to be produced with them. Thus, Wagner, for instance, employs their beats to emphasize the weight of suspense or fear, an approaching climax in the drama, and many other important points.

MECHANICAL INSTRUMENTS.

Any instrument capable of producing music automatically may be set down under our present heading. Mechanical musical instruments have been known very long, but in no case did those early automata reach a satisfactory stage of development. It was not before the eighteenth century that the first satisfactory mechanical musical instrument was produced. This was the music-box.

The music-box was invented and made in Switzerland since the middle of the eighteenth century. You have all seen this instrument in one form or another. It consists of a cylinder dotted with metal plugs, which are so arranged that they strike a series of steel bars when the cylinder rotates. Each of these bars vibrates and produces a different tone, the rapid succession of which produces music. Essentially, this is the entire inner mechanism of the Swiss music-box. Of course the cylinders must be turned by a crank, but whether this is done by winding up a spring or by electricity is immaterial. Some of these boxes are, however, very complicated, and good ones are always costly. The number of pieces they play, however, is very limited.

The Regina music-boxes are the most perfect of the kind. In them the zinc disk replaces the cylinder, and the rotation is horizontal or vertical, but always in a plane. This disk (about eighteen inches in diameter), is perforated so that each perforation will touch and vibrate a special vibrator underneath the revolving disk—the aperture releasing a tiny hammer-bar as it passes, is the whole secret of sound-production. Some of these Regina boxes are provided with sounding boards, which increase and project the sound. All the nickel- (or penny-) in-the-slot music machines work somewhat in the same manner. There are automatic banjos, chimes, and several other instruments of this character, which usually afford more diversion than real musical entertainment for the coin inserted.

The phonograph, in its perfected form, is a mechanism capable of furnishing fun and music in about equal proportions. It is now the most popular of all mechanical musical instruments, and hence need hardly be described. The most interesting point about phonographs is making a ‘‘record’’—that is, impressing a series of minute grooves upon the disk—but that we cannot enter into at present. If you have the inclination, you can readily get at this elsewhere.

Everybody knows that it was Edison (the great Thomas A.) who invented the phonograph. The year was 1877, and from that day to this the American inventor has been continually improving his invention, one of the greatest of the age. The machine now takes impressions so readily and reproduces them so faithfully that many non-musical uses have lately been found for it—such as taking dictation to be transcribed later by stenographers, recording (verbatim or stenographically), court proceedings as rapidly and accurately as any court stenographer. But with these we are not now concerned.

If you have not seen a musical phonograph in operation—and with so many of them in use it were a miracle if you have not—perhaps a brief introduction will help you to a better understanding of it when you do come upon this machine. In its general action, the phonograph somewhat resembles the better music-boxes. Here, too, there is the impression upon a disk, which revolves in a plane about a central axis. The delicate spiral groove cut in the surface of the disk or cylinder, being connected by means of a steel point with the horn-like sound receiver, causes the vibrations when the cylinder is set rotating. The small indentions, or sound markings previously made upon the cylinder's surface, now cause the steel point just mentioned to rise or fall as the indented surface passes beneath it. Thus the vibrations are transmitted and the registered record made audible in the form of music. The metallic sound characteristic of phonograph music has lately been suppressed in a measure by using a wooden horn and by inclosing the instrument in a wooden cabinet. That it can ever be eliminated entirely is perhaps too much to expect.

The piano-player is undoubtedly the most perfect mechanical musical instrument in the world today. Although the principle embodied in this musical mechanism was known since 1880—when it was first applied to wind-instruments called æolians—it was applied to the piano only in 1898, attaining its present improved form somewhere about 1904. In its first stages of development, the player was detachable from the piano, but later it came to be built in the latter. The mechanical principle, however, is the same in either case. Let us see how the mechanism works in producing music, taking the detachable player for convenience of explanation.

A cabinet frame, resembling a small roll-top desk, is all you will see of a detached piano-player when out of action. As the top is rolled back, a row of levers is disclosed to the eye. These levers, padded with felt or leather, can be made to move up and down by pneumatic suction produced by pumping air into a receiver within the instrument; and you will see two pedals provided for this purpose. Each little lever is connected with its own rubber tube, and, if you should open the instrument you may see a whole network of these thin tubes, like so many telegraph wires, crossing and re-crossing within the instrument.

Let us now move this player close in front of the piano so that the padded levers rest directly over the keys of the piano, sit down and commence pumping air by means of the pedals we have mentioned. Will the piano play? Not in the least. For we have yet to insert ''the roll,'' a most essential factor in piano-players. This is a long strip of perforated paper of durable quality, wound on a spool, which performs for the piano-player a function similar to the disk of the music-box or the cylinder of the phonograph. Now, this music roll, being fastened above what is called ''the tracker-board,'' will unwind when the pedals are worked, and only then is music produced. But how?

As the roll passes over the tracker-board, its perforations sometimes exactly coincide with the longitudinal slots in the latter, which are connected with the numerous pneumatic tubes already referred to. Every opening that thus becomes continuous sends air pressure directly upon the lever, which strikes a key on the piano, to bound back as soon as the connection ceases. Since the perforations are the score of the given pieces of music, continuous pumping will thus perform the entire piece. It remains only for the operator to manipulate a certain number of attachments—such as will regulate the tempo and the volume of sound—to render the performance satisfactory, which is easily done from clear directions marked on the roll as it unwinds. The other type of player—that which is embodied within the piano—works in exactly the same way, save that the little levers, instead of striking the keys, strike the strings more directly—which is, of course, an advantage.

Today almost every make of piano can be had with piano-players, of which more than a hundred varieties surely exist. There is one type of player which deserves special mention—the electric player. In this there is no pumping needed and no pneumatic tubing. The whole mechanism is worked electrically and from a distance. The only thing that a careful eye could detect on the piano itself is a series of rods and levers directly under the keyboard. Each of these is connected with a corresponding key above, and, when electrically charged by the machine, will depress it to produce the desired note. Either an electric current or a storage battery will operate this type of player, which can be controlled as to tempo and volume of sound like the other kind, or may be left to do even this automatically. The rolls, being made of metal, are both more compact and more durable than those of the pneumatic players.

From all appearances, piano-players have not only come to stay, but have opened a new era in the history of music. By means of this invention reading music is now as easy as reading words. Great musical composition can be studied by means of these player-pianos just as literary masterpieces by means of the printed page. Like all novelties, the piano-player is susceptible of much abuse, but to sincere music lovers it already affords the means of a musical education never before possible.

CHAPTER LXII.

Glass.

WHAT GLASS IS MADE OF.

EVERY kind of glass consists of silica, derived from some form of sand or quartz, and several other basic materials, such as lime, potash, and soda, with certain oxides of the metals—lead, zinc, iron, copper, and even gold and platinum. The mixture of these materials, under the influence of heat, produces a substance which is usually transparent, is entirely without structure—that is, not crystalline—and which varies in color from transparency, through the whole range of rainbow hues; and it may even be made devoid of color—black.

The actual manufacture of glass and glass articles is by no means so simple as the foregoing statement might lead one to believe. Indeed, the greatest skill and ingenuity, as well as care in the selection of materials are necessary, if one would attain, in their perfection, the remarkable results that are now secured in glass manufacture.

MELTING AND COOLING.

Furnaces used for making glass must be able to withstand the effects of vapors arising from red hot substances. These substances, in the manufacture of common window glass, are sand, lime and soda. The sand may be found on some seashore or river bed; the lime is produced from any convenient limestone burnt in a kiln; and the soda consists of common soda-ash, which is ordinarily used in our households in the form of soda crystals or sal soda. When this mixture is melted in a fire-clay furnace, it first produces an opaque, milk-white mass which has to be kept in the fire a number of hours. After it has stood in the crucible awhile, the lower part becomes transparent, and, if allowed to stand a longer time, the transparency extends through the whole mass. This change in clearness is due to the melting process, which drives out the carbon dioxide, or carbonic acid gas, as it is called. If the crucible is now removed from the furnace and allowed to cool somewhat rapidly, it will be found that the mass becomes "shot" with cracks, called fractures, due to unequal cooling. The glass is now devitrified—that is, has lost its glass-like character. If, however, the whole mass is allowed to cool down slowly, the resultant material will be found to be of a truly glass-like character, which we call vitreous.

THE PROCESS OF ANNEALING.

This process is called annealing, and is sometimes accomplished in another way. The glass is removed from the furnace in the form of finished objects, and then dipped into a bath of warm oil and allowed to cool with it. They are "tempered-glass" articles, and are remarkable for their unbreakability. This method of tempering glass, however, is not often used, for the simple reason that the results are uncertain, and also because it is quite difficult to make the annealing a success. The usual manner, therefore, is to make the objects first—the bottles and glasses—and then put them into hot ovens formed like tunnels, sometimes a hundred feet in length. The articles are placed at the hottest end of the oven, and are gradually moved on a traveling platform toward the cooler end; by the time they arrive there they are sufficiently cooled to be handled and packed for shipment.

ONE WAY IN WHICH WINDOW GLASS WAS MADE.

Window glass was originally made by a blower who stood in front of the furnace and, dipping a long iron tube into the crucible of melted glass, blew through the tube upon the adhering mass, spinning the tube meanwhile. This caused the glass to spread into a large thin sheet, which was gradually removed to a cool place and then put into an annealing oven to be tempered. It was finally cut into sheets of the desired size, and formed the old-fashioned window glass. One fault in this glass was, that a welt was left at the point of contact with the tube. It is a mark of ancient glass-making, however, and glass with such welts, found only in very old houses, is much prized by curiosity seekers.

THREE WAYS IN WHICH IT IS MADE.

One of the present methods of making sheet glass is to take from the crucible as much molten matter as will adhere to a blow pipe or iron tube, and blow it over a pit, swinging it, meanwhile, like a pendulum. By this means the glass is blown into the shape of a cylinder sometimes six or seven feet long, the diameter being determined by the thickness of the glass to be made. These cylinders of glass are then carefully placed in ovens where they are split along their length and opened, thus forming a flat sheet, which is then ready for annealing.

Sheet glass is also made by rolling it just as the cook rolls a piece of dough. The glass is taken from the furnace with a spoon or ladle, and poured upon a table that is kept hot with superheated steam passing through tubes on the underside. In this way the glass cools slowly, as a steamheated roller passes over it and spreads it out into a thin layer. Any kind of figure or design can be impressed upon the surface of the glass by corresponding drawings upon the table. It is thus that ribbed glass, netted glass, and figured and ornamental glasses of many varieties are made.

Certain kinds of window glass contain netted wire, a fine meshed variety of ''chicken wire.'' This is put in by rolling out a sheet of hot glass, and placing upon it, while still hot, a sheet of the wire; another ladle of hot glass is poured over it, while the rolling is still going on, and the wire is thus made prisoner. This glass takes a fine polish and has the great advantage of not breaking up when fractured. It is sometimes called ''fire-retardant glass,'' because it will resist a conflagration longer than ordinary glass would do. This has been one of the most important advances in the manufacture of sheet glass in the last twenty years.

HOW GLASS VESSELS ARE MOLDED.

To make goblets, tumblers, and articles of similar shape, molds of wood or iron are often used, into which the glass is blown. To strengthen the glass, thus obviating ''glass-strain,'' the newly blown objects are removed from the molds and annealed, as previously described. The result is a glass utensil that will withstand fairly well the knocks of ordinary usage.

It is interesting to note, in passing, that the inside of the iron molds are dusted with charcoal powder. The combustion of the charcoal forms a layer of carbon dioxide between the glass and mold, which gives a very high polish to the object when that is twisted in the mold. It also prevents adhesion, and facilitates the removal of the article from the mold.

THE MANUFACTURE OF CUT GLASS.

The beautiful cut glass, that reflects light in all the colors of the rainbow, must be made very heavy; to secure this density, litharge is used in addition to, or substituted for, the lime. The mixture is then forced into the molds under pressure, not simply blown in, as in the case of the tumbler. The cutting is, of course, a purely mechanical operation. It is performed by emery wheels, and in endless designs. For polishing, finely assorted grades of emery-powder are used, jewelers' rouge and chamois being employed for the finishing touches.

THE FLOWER OF THE GLASSMAKER'S ART.

If there is color in glass, due to impurities in the mixture, the color may be eliminated or neutralized by the addition of various chemicals, so that a glass is made which is nearly or quite white. On the other hand, very artistic and beautiful effects are produced by tinting glass, wholly or with only a surface coating; and the variety of colors that may be obtained is almost infinite. Cuprous oxide imparts to the object that rich ruby-red seen in the photographer's light; oxide of gold gives a magnificent Tyrian purple; and chromium produces emerald green. Cobalt makes glass blue; arsenic and phosphate of lime, opal; iron oxide, in the form of red oxide, amber and brown; and oxide of iron, mixed with a large proportion of lamp-black or even charcoal, produces black glass.

If a glass bottle is to be made red, for instance, an oxide copper is incorporated into the mixture of sand, lime, and soda. On being taken out, it has a greenish tint which changes to red under the influence of a "reducing flame"—a flare of smoky, carbonaceous fire.

A white glass may receive a colored coating, and then be sent to the glass cutter, who cuts through the "skin"—a ruby skin, we'll say—exposing, in figured and decorative designs, the white glass underneath. One can readily imagine the rare and artistic effects that may thus be produced. They are the perfection—the very flower—of the glass-maker's art,

CHAPTER LXIII.

Fireworks.

BRILLIANT AIDS TO THE GAYETY OF NATIONS.

THE art of pyrotechnics, or the making of fireworks, is of unknown antiquity. It was first practiced among the Chinese in remote ages, and has attained with them a perfection unapproached in other countries. In the fourteenth century the art was introduced in Italy by the Florentines, and since that time Italians have always stood at the head of European pyrotechnists. Most of the fireworks that we see, especially of the more elaborate kinds, are manufactured by the Chinese.

Fireworks are made in such a way that when a flame or heat is applied to them they ignite and burn completely, without the intervention of air, and produce various colored flames according to the metallic substances that are component parts of the mixture, which must be made to be completely combustible by the compounds containing oxygen which are mixed in it; and the combustion must produce heat enough to turn the metallic substances into vapor—for it is the vapors that give color to the flames. By the application of this principle a large variety of effects are produced. For example, certain metallic grains, such as the grains of iron, magnesium, and aluminum bring out magnificent scintillations or sparks which are very beautiful when mingled with colored flames. The silver-white light of these materials makes a very pretty star-like effect. Of course, each metal will give a certain color; antimony and copper give shades of blue, the antimony being lighter than the copper.

Copper alone gives a brilliant blue of a very attractive shade. Shades of peach color or lavender are produced from the salts of potassium.

DANGER IN AMATEUR FIREWORKS MANUFACTURE.

Since all these mixtures are highly combustible, and burn very rapidly when a flame is applied to them, it is not wise to have them around our homes, as the least increase of temperature will sometimes start combustion; in fact, these materials are generally ranked as explosives. Many serious accidents have occurred from carelessness in the handling of the materials from which fireworks are made. Furthermore, it is not wise to attempt to make them unless you are an expert at the art, for the results of amateur efforts in this line are almost always a failure and are frequently disastrous. When you wish to ''celebrate,'' it is much better to buy fireworks from regular manufacturers who have made a study of the particular conditions under which the mixtures may be manufactured.

INTENSE HEAT OF PYROTECHNIC MATERIALS.

When it is remembered that fireworks contain enough oxygen to make a complete combustion of the mixtures, and at the same time produce a temperature sufficiently high to burn the metals into vapor and give color to the flame, it is easy to understand how intensely hot these flames are, and how painful may be a burn from such combustions. In addition to this fact, it must be kept in mind also that a number of the materials used in fireworks are extremely poisonous when they get into open wounds. So we only refer to the general principles upon which fireworks are manufactured and used, but do not go into particulars that will enable our readers, unless skilled in the art, to attempt to make fireworks for themselves.

CHAPTER LXIV.

Aeroplanes and Airships.

REALIZING THE DREAM OF AGES.

THE navigation of the air has appealed to the imagination and ambition of man for thousands of years, but up to only a few years ago it appeared to be an unanswerable puzzle. But the invention and application of gasoline engines gave so stimulating an impulse to the dormant science of flight, that at the opening of the twentieth century man suddenly built himself wings; he flew with so certain a success that, now, the flight of numerous aeroplanes for hundreds of miles is taken as a matter of course.

TWO WAYS OF AIR SAILING.

There are two distinct modes of navigating the air:

(1) By aeroplanes—machines heavier than air, that are supported on it only because of their motion.

(2) By airships—navigable or dirigible balloons, that float in the air by reason of the supporting power of a lighter gas.

We shall consider these two modes in detail.

AEROPLANES.

THINK OF AIR AS A FLUID.

Aeroplanes are machines much heavier than air, that are supported on it because of their motion.

To understand how this is possible, it is necessary to know clearly what air really is. Because we breathe it, and can not see it, there is a tendency to think of air as a weightless gas that we can not hold or confine.

Of course this is not true. A cubic foot of air has a certain weight, just as a cubic foot of iron, or wood, or any other substance.

The best way to appreciate what air is and the nature of its movements, is to think of it as a fluid, like water. If a bag is filled with water and taken out into the open air, it drops to the ground, when unsupported, because the water is heavier than the air. Likewise, if a bag full of air were placed in an atmosphere of hydrogen, it would fall, when unsupported, because the air is heavier than the hydrogen. So there are different grades of fluids, some heavy, as water, others, like air, much lighter, but all of the same nature; there exist motions of air in streams and currents that are similar to water. In fact, the atmosphere is nothing but a huge ocean of air with waves, and tides, and currents, that closely resemble the sea.

A FLUID FLOWS IN STREAMS.

Air, therefore, has weight and movements of its own. A current of air is called wind. We feel the wind and see it blow things over, because air has weight, and when a stream of air strikes an object, it exerts a push on it. In order to exert such a push, or pressure, the air must move or be moved, and the faster the air flows by a certain object, the greater is the force it exerts on that object.

YOU PUSH AGAINST A STREAM, OR IT PUSHES AGAINST YOU.

It is not always necessary for air to flow past an object to give a force or push of this kind. The object may move through perfectly still air—you know with what force the wind strikes against you when you are riding in an automobile. There is no difference between a wind like this—caused by motion—and a real wind felt when standing still. In both cases, there is a relative motion of the air and the object against each other. Either may be standing still or both may be in motion, but there never is any force or push given by the air on the object, when both are standing still, or when both the air and the object are moving in the same direction at exactly the same speed.

IT'S THE "PUSH" THAT COUNTS.

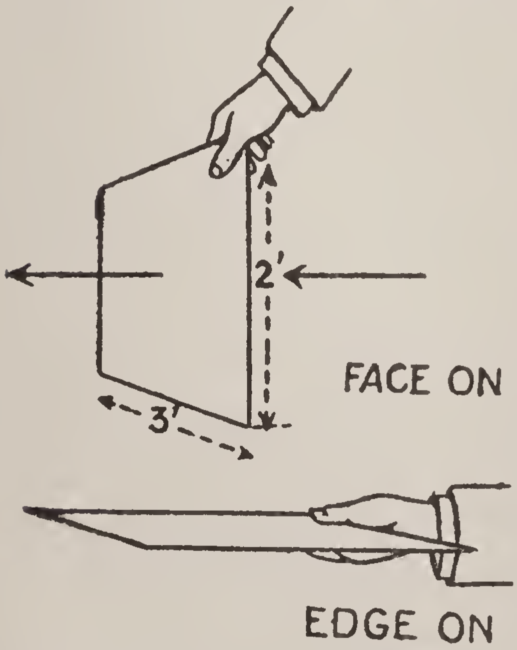
Relative motion of air past an object is necessary, in order that the air may exert a pressure on the object.

It is now easy to go one step further, and see that, whenever any object is to be moved through air, there must be a push or pull on the object. In other words, there is a resistance to motion of any object through air, because, as soon as it starts to move, the air begins to use its force against it and try to keep it from moving. This is what is called "air resistance," which is the opposite to air force or pressure. A familiar application of air force is the way in which the air blows on a sail; by thus causing a force, it moves the boat.

HOW AIR ACTUALLY HOLDS THINGS UP.

The next idea to grasp is that air can support properly shaped things.

The air can exert force on a surface when the latter is moved in air, horizontally; it can do the same if the surface is moved vertically up or down, or, in fact, in any direction. The air is still; it is the surface that moves; and, to get an air force on it the surface may be moved through the air in any way. Therefore, if we take a flat surface and move it vertically down, quickly enough, the air will exert a force on it that will act upwards against the surface and tend to support it. In the same way, if we move the surface up vertically, the air force will tend to push it down.



To illustrate this, take a large piece of light cardboard, about 2 feet by 3 feet, and, holding it at arm's length, as shown in the diagram, move it "face on," in any direction, and the pressure is actually felt; move it, first very slowly and then quickly, and you prove the fact by evidence that, the quicker it is moved, the more the force is exerted.

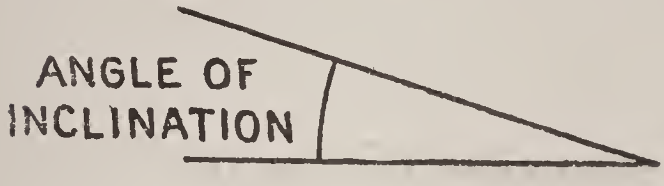
WHAT THE SIZE OF THE OBJECT HAS TO DO WITH IT.

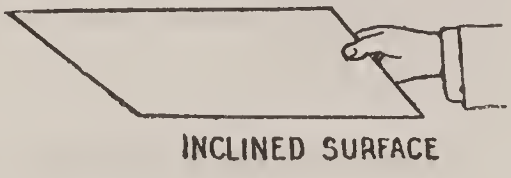
There is another fact to be learned that is very important, and this is that the size or magnitude of the air force depends on the size of the surface. Movement of the surface through the air causes the air to give a certain push on every point of the surface, but the strength of this is independent of the size of the surface. It merely acts at every point, and the bigger the surface, the greater the number of points upon which all these little forces can act. The sum total of all these unit-forces, is the whole force acting on the surface. Therefore, the larger the surface, the larger will be the whole air force acting on it. This can also be illustrated by first moving the large cardboard surface at arm's length, and then doing the same with a visiting card. Because of its small size, the whole force on the card is almost nothing, but actually the air force at every point is the same as at every point of the cardboard. If the cardboard is moved "edge on," through the air, the force felt is very small, because the surface that the air hits is only the very narrow edge of the cardboard.

Up to this point, we have been considering surfaces that are moved flat against the air in any direction, and we find that the air presses on the surface with a certain force that is greater in exact proportion to the area of the surface and rapidity of the movement.

THE ANGLE ALSO IS A FACTOR.

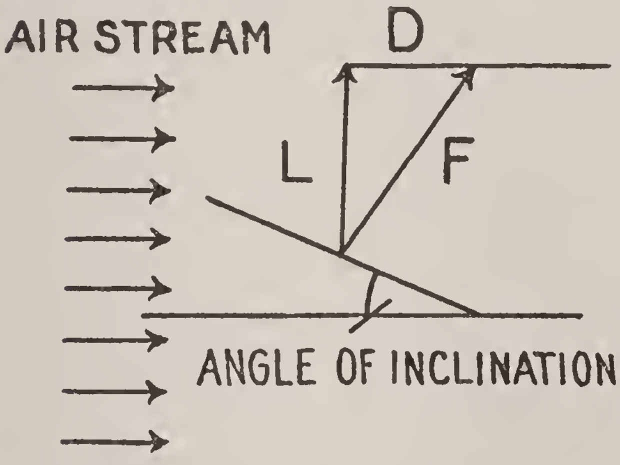
Now it is necessary to consider inclined surfaces. If, instead of moving the cardboard "face on" or "edge on," we incline it so that the front edge is raised and the rear edge depressed, as shown in the diagram, then the surface is at an angle of inclination to the horizontal. If it is swung at arm's length horizontally in this position, the air force is distinctly felt to act upward under the surface. At the same time, a resistance to motion is felt exactly as when the surface is moved "face on," only the resistance is now much smaller. Therefore, as soon as we incline a surface, the resistance begins to decrease, and, at the same time, a lifting force begins to act. The smaller the angle of inclination, the less the resisting force, and, proportionately, the greater is the lifting force.





"LIFT" AND "DRIFT."

Thus, on the diagram, we can represent this resisting force by D and the lifting force by L. The whole force acting on the surface is F, and just as when the surface was moved "face on," this force depends on the speed and the size. L and D are merely parts of this total force F, the part L acting as a lifting force, and the part D as a resisting one. L is called the "lift" and D is called the "drift." Now, if we wish to move this inclined surface through the air, the force with which we must push it is equal and opposite to D. Upon being moved in this way, the surface will exert an upward lifting force, L. This is the theory of the aeroplane.



The necessary requirements, therefore, for lifting anything by the force of the air are (1) a surface for the air to act on; (2) inclination of the surface; (3)

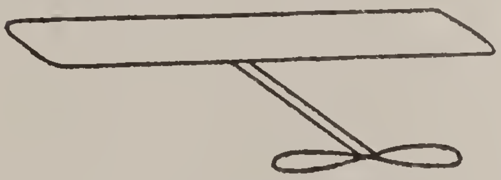
sufficient speed to make the total force on the surface so great, that its lifting part will at least be equal to the weight the surface carries. It must be clearly understood that inclination and motion give rise to the lifting force.

THE AEROPLANE A COUNTERPART OF AIR FORCES.

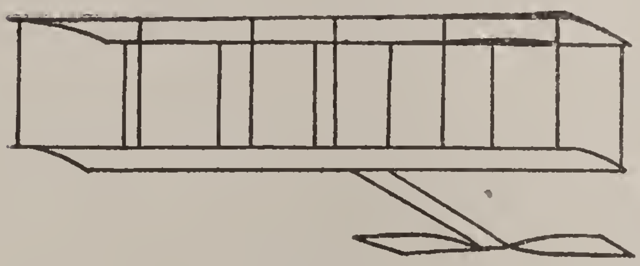
An aeroplane is a machine or apparatus that is equipped, primarily, with large surfaces, set at an angle to the air current and moved relative to the air so that the air force acts on the surfaces and supports the machine. Before it can be supported, however, the air must be moved past the surfaces at such velocity as is required to make the lifting force larger than the weight of the machine. As soon as this takes place, the aeroplane rises in the air.

VARIOUS TYPES OF AEROPLANES TO UTILIZE DIFFERENT FORCES.

In a motor-aeroplane, the air is moved past the surfaces by the propulsion of the machine itself through the air.



MONOPLANE



BIPLANE

In kites, which are motorless aeroplanes, the surface is held stationary by the string, and the air moved under it by the wind.

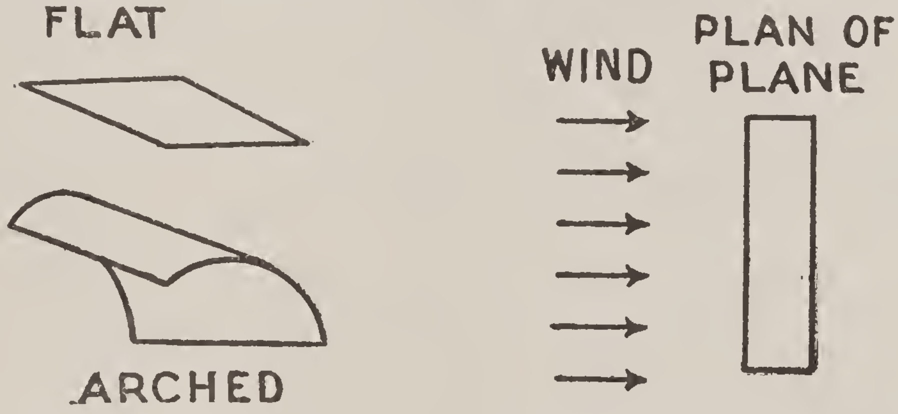
In gliders — man-carrying aeroplanes, without motors — the machine floats down on the air, and in doing so, goes forward, thus causing the air to move past the inclined surfaces and give some support. This makes the fall a gradual descent, instead of a sudden drop.

The inclined surfaces of aeroplanes are usually called planes. A machine that has one large inclined supporting plane, is called a monoplane. A machine that has two inclined supporting planes is called a biplane. The planes are usually constructed of cloth stretched over a light frame of wood.

THE SECRET IS IN THE "LIFT."

The principle of support is always the same. The rigid plane surface is spread out to catch the moving air, and the plane is so inclined that part of the air force lifts and part opposes motion; but that opposition is overcome by the driving power.

As it is necessary to get as much lift and, at the same time, as little resistance as possible, the planes of an aeroplane are not flat, but arched, as shown in the diagram. In addition to this, the plane is made oblong, with the largest edge facing the wind. This greatly increases the lifting power.



If the angle of inclination is changed, the lifting power will change. If the angle is decreased, the lift will decrease and, when the angle is raised, the lift increases; but the weight of the machine always stays the same. So, when the machine tips up—the angle of incidence being thus increased—the added lift causes the aeroplane to rise. In the same way, when the machine dips down, the angle of inclination is decreased and the aeroplane drops, because there is less lifting power.

Therefore, in order to keep the machine flying in a horizontal line, the angle of inclination must be set to give the same lift all the time. But we have already learned that the air is an ocean full of waves and currents. The air is not perfectly still; it is moving in all sorts of complicated ways. These movements tend to change the relative motion of the air past the planes, and sudden puffs and gusts tend to upset an aeroplane. These changes, however, take place rather slowly and can be offset by so changing the angle of inclination that the lift will stay the same. And, to preserve the equilibrium by thus changing the angle of inclination, rudders are used.

NATURALLY, THE LIFT IS REGULATED BY "ELEVATORS."

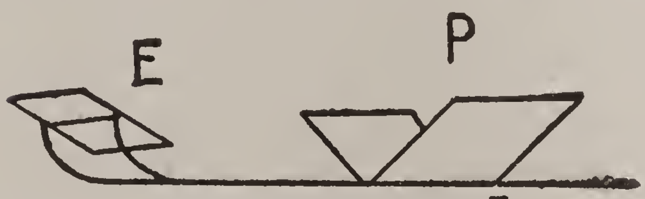
Rudders so used are called "elevation rudders," or "elevators." They are operated by the aviator, the man who drives the aeroplane. He can, by use of his elevator, actually make the machine rise up, or dip down, or keep on a horizontal course, as he desires. In other words, by means of the elevator, he controls the height at which the machine flies.

TWO ELEVATORS—FRONT AND REAR.

There are two types of elevation rudders:

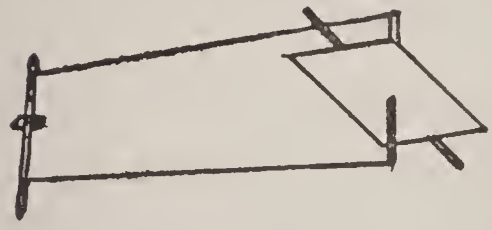
(1) The front elevator.
(2) The rear elevator.

The front elevator consists of a surface (similar to the cardboard surface previously mentioned) that is pivoted, as shown in the diagram, and that can be turned up or down. Its inclination can, therefore, be changed at will, and it exerts a lifting force, exactly as does the main plane of the aeroplane—the lifting force increasing the more the rudder is turned up from the horizontal. This smaller surface, or elevator, is mounted on framework out in front of the large main supporting planes. The aviator on many types, such as the Wright and Farman,



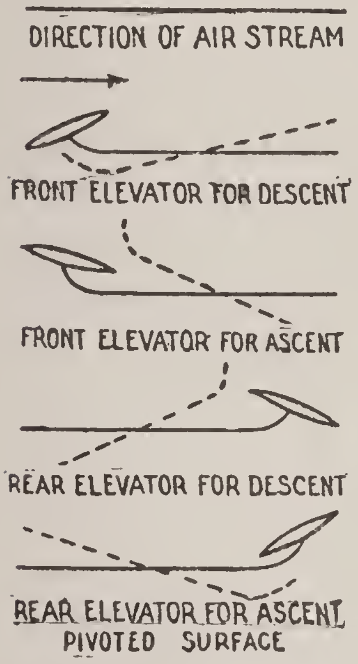
FRONT ELEVATOR E
IN FRONT OF MAIN PLANES P

controls the elevator by a lever. To the lever, as shown on the diagram, there are attached wires that lead to the rudder, so that, when the lever is pulled in by the aviator, the elevator is turned up more. This causes the lift of the rudder to increase, and therefore the machine will tip up and rise. To make the aeroplane descend, the lever is pushed out, thus turning the elevator down. This decreases the lift at the front, makes the front of the machine sink, and causes the entire aeroplane to descend.



Lever Control

The rear elevator is a similar small surface, or plane, placed on framework at the rear of the aeroplane, instead of at the front. This type is used on the Bleriot and Antoinette monoplanes, and many others. It is operated in the same way, but there is this distinction: Instead of lifting up the front to increase the inclination of the main planes, and thus make the whole aeroplane rise, it is merely necessary to press down the rear. Therefore, for ascent, the lift of the rear elevator is decreased, thus causing the rear to sink. Obviously, this tips up the entire aeroplane, the same as if it was lifted at the front. To descend, the lift of the rear elevator is increased; this pulls up the tail of the aeroplane and causes it to dive downwards.


DIRECTION OF AIR STREAM
FRONT ELEVATOR FOR DESCENT
FRONT ELEVATOR FOR ASCENT
REAR ELEVATOR FOR DESCENT
REAR ELEVATOR FOR ASCENT
PIVOTED SURFACE

STUDYING BY MODEL.

The simplest way to understand the elevation control of an aeroplane is to make a simple model. For example, take a piece of cardboard and attach it by its front edge to a long and light stick. Fix it so that it is at an angle of inclination, as shown on the diagram. Then, with the stick balanced in various positions the different ways in which the stick will tip, illustrate perfectly the operation of the elevator. A still better way is to pivot the surface on the end of a frame, and turn it at various inclinations. The action is illustrated in the diagram.

ELEVATORS THAT MUST BE DIRECTED.

It is also necessary to equip an aeroplane with a direction rudder, a rudder that is used to steer the machine from right to left, exactly as a boat is steered. The direction rudder is almost always at the rear of an aeroplane, and, of course, is a vertically placed surface. It is moved precisely like a boat's rudder, and is used for keeping the machine on a straight course, or for turning it to either side. It, therefore, controls the direction in which the aeroplane flies.

SEESAWING ABOUT A PIVOTAL POINT.

There is one other way in which an aeroplane can tip, since it is freely suspended in the air. It can move sideways, the right side going down and the left up, or vice versa. This sidewise movement is entirely distinct from any change in elevation or direction. It is merely a swinging or ''seesawing'' of the machine about the center.

The control and correction of this motion was one of the most important and difficult problems that inventors had to solve, and the discovery and application of a simple method by the Wright Brothers, was one of the greatest discoveries in aeroplaning. Other devices have since been invented.

TWO WAYS TO SEESAW.

The control of this side-tipping is usually referred to as ''transverse control,'' and there are two main methods in which it is now accomplished:

(1) By ''warping'' the planes.
(2) By the use of ''ailerons'' or balancing planes.

WHERE "WARPING" MEANS "TILTING."

We have already learned that changing the angle of inclination of a plane alters the lift. It is easy to understand, therefore, that if, on a given plane, we increase the angle of inclination on one side and decrease it on the other, then the side with the largest angle of inclination will lift up and the other will become lower, so that the whole plane will cant over sideways, with its right side up and its left down.

Planes of aeroplanes are so constructed of wood and cloth that this process of "skewing" or "warping" the plane is rendered possible. Warping is merely a twist of the surface about the center, so that the inclination at one end is increased and at the other decreased. This twisting motion is operated by a suitable system of levers and wires and is entirely in the control of the aviator. By means of it he can not only cause the machine to tip up sideways, but, if a sudden gust of wind has tipped it up, he can actually bring it back to an even keel. The aeroplane is thus controlled transversely, by altering the shape of the main surfaces themselves. The side with the greatest angle of incidence has the greatest resistance, or drift, and therefore tends to slow down while the lowered side speeds around. This overcomes the balancing action, and necessitates the operation of the direction rudder to counteract it. The direction rudder is consequently always moved to the side of the least angle of inclination, in order to increase the resistance of that side and keep it from spinning around. In making turns, it is customary to incline the machine with the lower end on the inside of the turn, just before the turn is made. Then the surfaces are set normal and the direction rudder moved over for the turn, which is thus made much sharper.

HOW THE BALANCING PLANES WORK.

The other method of transverse control of an aeroplane is the same in principle, but, instead of actually altering the angle of inclination of the planes themselves, small balancing planes, or "ailerons" (wing tips) are placed, one on either side. The operation of these consists in increasing the angle of inclination of the tip on the side that is to be raised, and decreasing that on the side to be depressed. The balancing planes exert a lift in proportion to their inclination, just as does the elevator.

A model made of cardboard surfaces set at opposite angles of inclination on either side of a slender stick, will, when moved, readily tip sideways.

FOR CALM OR STORM.

We thus see that there are three ways in which an aeroplane is controlled. It is moved up or down (elevation); it is steered (direction); and it is controlled sideways (transverse control).

The importance of the rudder and side-control provision in an aeroplane can not be overestimated, as its entire ability to remain for any length of time in flight depends on its keeping steady and on the success with which the aviator can fight gusts that would otherwise upset him. On the calmest days an aviator must constantly be operating and jockeying his rudders, and one has but to see his ceaseless movements to appreciate the great difficulty of keeping an aeroplane steady. It may readily be observed how even the large soaring birds must keep their wings moving almost continuously, thus balancing themselves, delicately, on the shifty currents of the air ocean.

OVERCOMING "DRIFT."

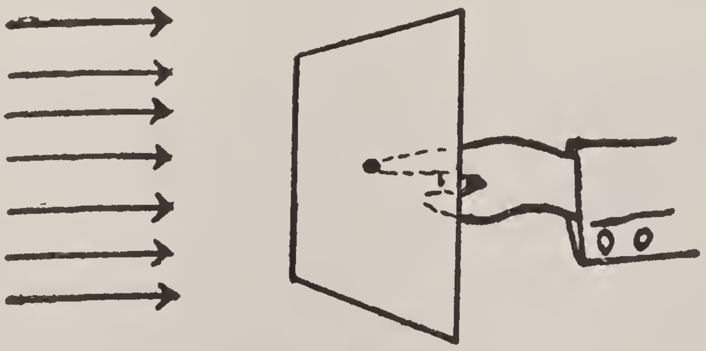
The resistance as offered by air to the motion of an inclined plane, or aeroplane, has already been mentioned. This resistance, or "drift," tends to offset any motion against it, and, in order to drive the aeroplane through the air at enough speed to get the necessary supporting force, or "lift," the corresponding "drift" must be overcome. On ordinary aeroplanes this is done by a propeller, closely resembling the screw propeller of a boat, except that, because of the lighter nature of air, the blades are made longer, and narrower, and are rotated faster. One or two propellers are used on aeroplanes, and they are placed either in front of or behind the main planes. Propellers, at present, are usually made of wood, and have two blades. They are rotated at from four hundred to one thousand five hundred revolutions per minute and, by their action in moving the air and the resistance the latter sets up to such motion, they exert a thrust, push, or pull on the aeroplane.

Propellers on aeroplanes are universally driven by gasoline motors, resembling automobile motors, because these give the greatest amount of power for the least weight.

It is found in practise that propellers which are of large diameter and are rotated slowly give better results than propellers of small diameter, rotated very fast.

LITTLE FORCES AND THE "PIVOTAL POINT."

The air force acting on a plane has already been described as consisting of a lot of little forces acting at every point. The whole force can itself be represented as concentrated and acting at one point. Thus, if we take the cardboard surface and hold it "face on" in a wind, there is a point, about at the center, where we can hold



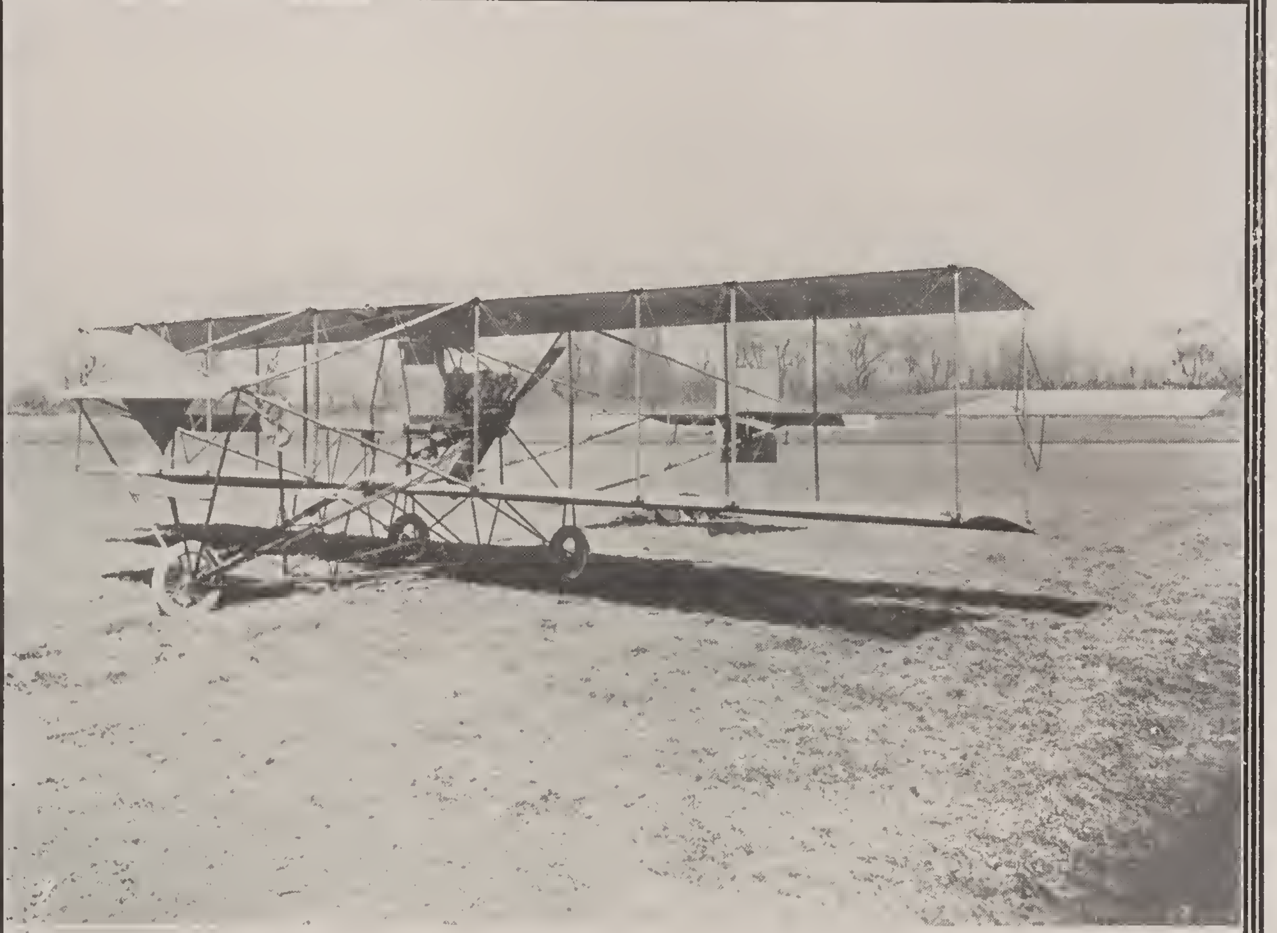
Center of Pressure

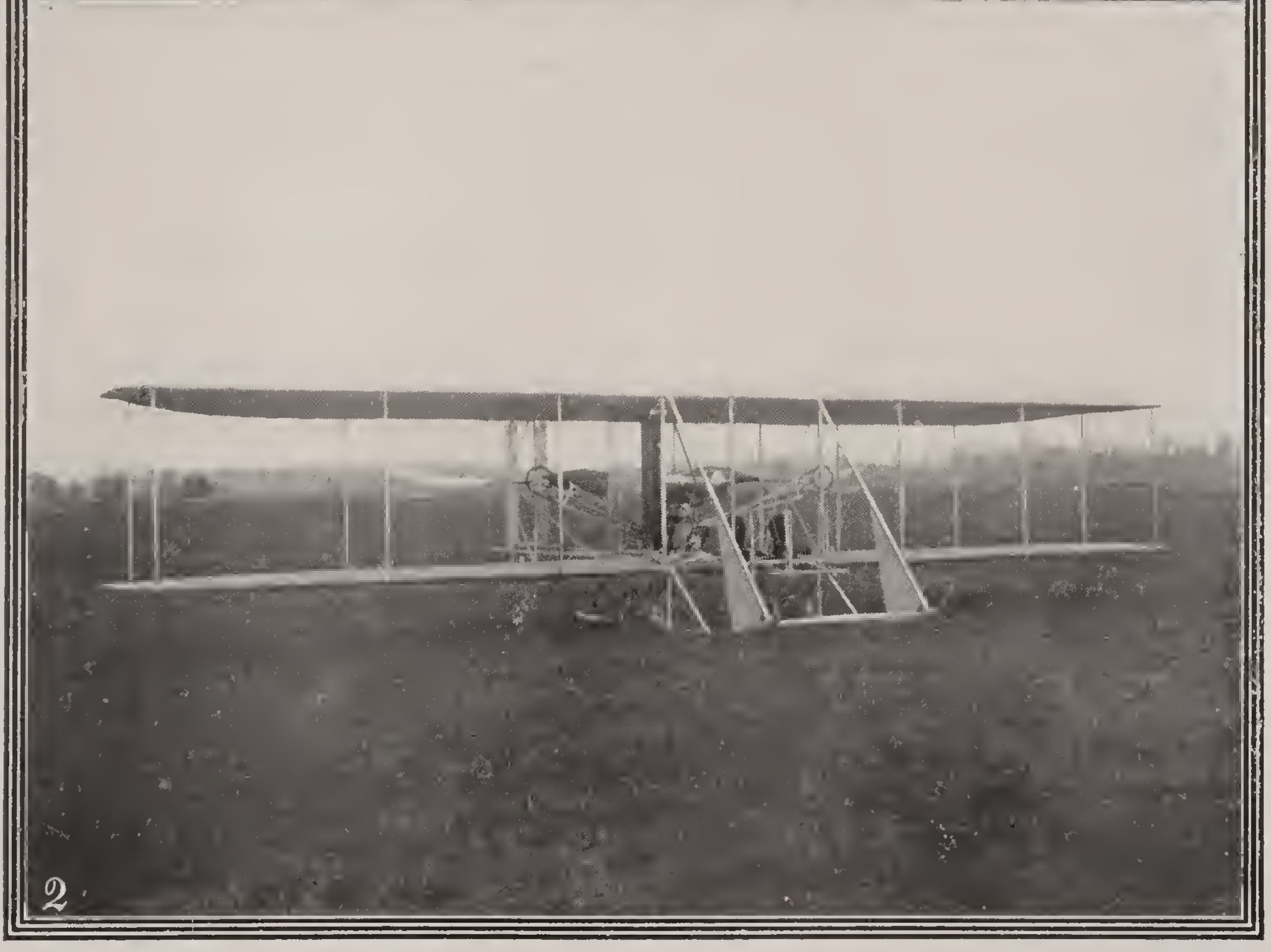
the surface perfectly steady. This center of the forces, or point of application of the total force, is called the ''center of pressure.'' As the flat plane is inclined down from the ''face on'' position, the ''center of pressure'' moves forward from the center of the surface. On curved planes, as the angle of inclination gets still smaller, it moves back again towards the rear. We see, therefore, that the point at which the plane must be balanced changes its position as the inclination is changed. This is an important phenomenon. At the point where the center of the supporting air force is, however, we must always have the center of gravity of the aeroplane; otherwise it will be out of balance. For example, if the center of pressure is back of the center of gravity, the aeroplane will dive down, and, if the center of pressure is in front of the center of gravity, the aeroplane will ''rear'' up. The motor and the aviator must, therefore, be so placed that their weight and the weight of the planes and rudders, will bring the center of gravity coincident with the center of pressure. The aeroplane is then in equilibrium, because the center of gravity is the pivot about which the machine will balance, and the center of pressure is the point about which it is supported on the air stream flowing under it.

GETTING A GOOD START.

In order to be able to roll along the ground to get up speed before taking their flight, aeroplanes are provided with rubber-tired wheels, fixed to the chassis or mounting. In addition, strong springs are used to lessen the shock of landing. The provision of a good strong, springy mounting, usually a combination of wheels and skids, is very important, as the jars of landing and of running over rocks, etc., often cause a great deal of damage.

We thus obtain an idea of the necessary parts of an aeroplane—motor, propeller and chassis—and of





1. A Curtiss Machine, the latest model bought by the United States Government.

2. The latest model of a Wright Flier.

the importance of placing these so as to give a proper balance.

THE MONOPLANE.

There are at present two great general types of aeroplanes. First, the Bleriot Monoplane, which is illustrated, a typical, one-surface machine. There is a main supporting surface divided into two halves, situated at the front of a long, central, tapering frame. The aviator sits in this frame at the rear of the plane. The plane is highly arched, as may be seen, and is made of a rubber cloth, covering a wooden and steel frame. The plane is held to the central frame by steel ribbons and guy wires. This aeroplane is mounted on two wheels at the front and a skid at the rear. The wheels are attached to springs made of rubber rope. The span of the plane from tip to tip is about twenty-eight feet, and its width from front to back about six and a half feet. The area is over one hundred and fifty square feet, and the weight carried is about seven hundred and twenty pounds. The air force, therefore, must be great enough to give a lift of four and a half pounds for every square foot of surface. This is actually obtained at a speed of about forty miles an hour, at which speed the entire aeroplane will leave the ground and soar into the air. The resistance to motion, consisting of the "drift" and the air force acting on other parts of the frame, is overcome by the pull of a two-bladed wooden propeller, which is placed at the front end of the frame and driven at high speed by a gasoline motor. At the rear of the frame are the rudders—a single vertical direction rudder, and a rear elevator, or horizontal pivoted surface, for raising or lowering the aeroplane. The main plane is warped for transverse control.

THE BIPLANE.

The Curtiss Biplane is a typical two-surface aeroplane. There are two main supporting planes, as is evident in the picture. In this type, ailerons, or balancing planes, are used for transverse control, and it is impossible to move the main planes in any way. The elevator is placed out in front and not in the rear, as on the Bleriot. The propeller is placed just back of the main planes, and the aviator sits in front of and between the planes. This machine is also mounted on wheels. The direction rudder is at the rear. There is also a fixed tail-surface at the rear. Tails, somewhat like a bird's, are used on several types, but they are not necessary. The Curtiss Biplane has an area of about three hundred square feet and a span of over thirty feet. The total weight is over eight hundred pounds, and at fifty miles an hour the air force on the two main planes becomes great enough to lift the machine clear off the ground.

TWO DEVIATIONS FROM THE GENERAL TYPE.

In addition to aeroplanes, proper, as we have here discussed them, there are two other kinds of flying-machines. But they do not depend on the principle of the inclined plane.

There is the helicopter or lifting-propeller machine, which is provided with propellers to lift it up, just as the aeroplane is provided with propellers to pull it along. The other type is the ornithopter, or flapping-wing machine, which is equipped with wings that are flapped up and down in imitation of a bird. Neither of these flying-machines, however, has as yet achieved any marked success.

A STEP TOWARD FLYING THAT YOUNG PEOPLE CAN TAKE.

The best and most practical way for young beginners to learn the vagaries of an aeroplane, is to make and fly small models. These can readily be made of silk stretched on a wood or wire frame, and can be fitted with rudders, etc., just as a large aeroplane is. The best model to follow at first, is the Bleriot monoplane. The model can be flown as a kite, or, better, may be equipped with a propeller. The most practical motive power to use in driving the propeller is elastic bands. A few brief trials will readily show how to alter the surface or rudder inclination, in order to make the model fly a straight course.

It is best to make the propeller as large as possible and have it rotate slowly. The rotation of the propeller tends to make the entire model turn in an opposite direction, especially if the propeller is large in comparison with the plane. This is one of the most troublesome and difficult things to regulate in a model; yet all that is necessary is to increase the inclination of the plane on the side that tends to turn down until the additional lift will balance the rotating tendency. It is best to make the span of the plane as much as six times the width and to curve the ends. If flexible wire is used, the arching of the surface may be changed at will, and much valuable experience gained. The angle of incidence should be about eight to ten degrees. For easy and successful model flying, the weight in pounds should be so proportioned to the surface area, that for every pound weight, there are two square feet of surface.

There is no better way than by model-building of learning the basic principles of a most fascinating science—the science of flying.

AIRSHIPS.

THE MACHINE AS LIGHT AS A BUBBLE.

Airships, or dirigible balloons, are huge craft that float about in the air ocean. They are totally different from aeroplanes or other heavier-than-air flying-machines, in that they do not require motion for support, and are actually lighter than the air they displace. In general, airships are much costlier than aeroplanes and very much slower. But a large airship can easily carry twenty-five to thirty passengers, while an aeroplane at present can hardly carry more than twelve.

A FORCE THAT TUGS BIG BUBBLES UP.

We have already mentioned how a bag, filled with water, will fall when unsupported in air, because the water weighs very much more than the volume of air that it displaces. We have merely to reverse this analogy to illustrate the idea of a balloon. A bag filled with air, when placed in a tank of water, will rise to the surface, because for the volume of water displaced the air is far lighter. In the same way, if we fill a bag with hydrogen, and make the difference between the weight of the hydrogen and the weight of the air it displaces greater than the weight of the bag, then the latter will at once rise in the air.

But due to the decreasing weight of air above it, the atmosphere becomes rarer and rarer as we go higher. The weight of a cubic foot of air is much less at a high altitude than it is at sea level. This is a familiar fact to those who have done any mountain-climbing.

There is, therefore, some point where the weight of air and the weight of the gas in the bag will become so nearly equal that the bag of hydrogen will cease to rise. It then merely floats about on the air, as a cork floats on water.

An ordinary balloon is nothing more than a bag containing a gas so much lighter than air that, upon being filled with it, the balloon develops an upward force and tugs so powerfully at its ropes that, the instant it is released, it shoots up into the air.

A BUBBLE THAT BECOMES A BALLOON.

Balloons have been used successfully for over a century, and men have made long trips, hanging in a basket from one of the bubbles of lighter gas.

But the balloon, because it merely floated about in the air, was entirely at the mercy of any wind current, and would have to go wherever the wind carried it. A balloon is completely immersed in a mass of air and hardly moves from it. No matter how violent the wind, occupants of balloons never feel it, because they are always going with the wind, not against it.

EVOLUTION OF "BALLOON" INTO "AIRSHIP."

To make navigation of the air by means of these floating airships a practical matter, it early became evident that some means of propelling and steering a balloon was necessary. And so many steerable and navigable balloons have been built, until, finally, we have the highly developed "dirigible" of today. This is being rapidly perfected, but is still so slow and so easily wafted about by winds that many believe it can never come into practical, everyday use.

A clear understanding of the nature of one of these huge dirigible airships may be gained from the fact that a large Zeppelin airship, with its twenty passengers aboard, is, when fully adjusted, so perfectly balanced in the air that a child can take hold of it and actually lift it up. The weight of this huge affair appears to be nothing, merely because it weighs exactly the same as the air in which it is floating.

It must be borne in mind, however, that while airships gain their support, in no way, from the air force caused by motion, this air force does act on them, just as on aeroplanes, by creating a great resistance to motion. As soon as the dirigible starts to move, the air offers resistance, and does so more strongly the faster the speed of the wind and the greater the size of the balloon.

This resisting air force or "air-resistance" is the greatest factor with which the dirigible balloon has to contend.

FIRST STEP IN THE EVOLUTION IS CHANGE OF SHAPE.

To reduce it to a minimum, the shape of dirigible balloons has been changed from the old spherical balloon to the shape of a cigar or pointed cylinder, which is made long and narrow for the purpose of offering the least resistance. This shape is sometimes called "fish-shaped," and a large dirigible does certainly present many points of resemblance to a fish or a submarine boat.

SECOND STEP—PUTTING AN ENGINE UNDER IT.

In order to drive it against the air and develop headway in the teeth of a wind, it is necessary to equip a dirigible with a strong and powerful propeller driven by gasoline engines. These propellers drive the airship forward in the same way that propellers drive aeroplanes, but on aeroplanes there are only one or two propellers, while on dirigibles there may be as many as six or eight.

THIRD STEP—MAKING IT GO IN ANY DIRECTION.

Dirigibles employ rudders for steering and also for elevating or depressing the gas bag, although, if the navigator desires to rise or descend any great distance, he must alter the amount of lifting force by changing the quantity of gas. If gas is let out of the envelope or gas bag, the dirigible will at once sink. If the dirigible is then itself lightened by the overthrow of ballast, the dirigible rises again. Alternate heating and cooling cause the gas in the envelope to expand and contract. Therefore, when exposed to the sun, the gas in the envelope becomes heated and the airship rises. If the dirigible then suddenly passes into a heavy cloud, the envelope cools and the gas contracts, so that the dirigible descends.

We see, therefore, that a dirigible airship consists essentially of a cigar- or fish-shaped envelope of some airtight cloth that holds the supporting gas, to which is attached a frame carrying the passengers, motors, rudders, and propellers. The envelope must be made of material strong but as light as possible, and the frame of light woods and aluminum.

THREE TYPES OF AIRSHIPS.

There are three main types of dirigible balloons:
(1) The Flexible.
(2) The Semi-rigid.
(3) The Rigid.

THE FLEXIBLE AIRSHIPS.

In the Flexible system the gas bag is not stiffened in any way by framework, but the pressure of the gas within is made so great that the envelope is fully distended, and thus tends to retain its shape. But as soon as an airship starts to move, the air force acting on the bow becomes so great as to cause the gas bag to bend and buckle, unless adequate provision is made against it. So, in the Flexible system, as on the Parseval dirigible, there are provided within the bag two smaller airtight envelopes, called "balloonets." These smaller bags inside the large one are entirely separated from it, and are never filled with supporting gas, but with air. A balloonet is rarely, if ever, inflated to its full extent. Its function is to fill all the spare room there is in the envelope, and, by pushing on the gas, cause the latter to distend and expand the envelope fully.

In the Parseval system, one balloonet is placed at each end of the gas bag. If the rear one is inflated and the front one allowed to collapse, then the bulging rear balloonet pushes the gas forward, where it has more room. This puts a greater quantity of lifting gas at the front, and consequently, because of the larger upward force, the front of the bag rises. The opposite is done to make the rear rise.

THE SEMI-RIGID AIRSHIP.

In the Semi-rigid system, a long stiff frame is fixed to the bottom of the gas bag. This protects the envelope against collapse, but adds greatly to the weight. A balloonet is also provided for this type. The French airships, *Liberté, Republique,* and others, and the German ships, *Gross* and *Krell,* are of the Semi-rigid system, as is the long and narrow British airship, the *Morning Post.*

THE RIGID AIRSHIP.

In the Rigid system, like the great Zeppelin airships, no balloonets are used. The envelope itself is built on a rigid frame and requires no internal pressure to keep its form. The rigid frame makes the airship much costlier and heavier, but it adds enormously to the strength, and permits the airship to be driven at much higher speed. In addition, as is often the case with the *Zeppelin,* the rigid form is preserved so well that the entire craft can be made to tack into the wind very much like a sailboat. The *Zeppelin* has elevation rudders both in the bow and in the stern, and they are so powerful that they act exactly like aeroplanes and can aid in supporting the airship. In fact, the Rigid type forecasts, possibly, a more pronounced combination of airship and aeroplane than has yet been produced.

BIG LINERS OF THE AIR OCEAN.

Dirigible balloons, at the present time, are being built of enormous size, some of them five hundred feet long, almost as large as big ocean liners. They are difficult and unwieldy to handle, and require immense harbors and houses, or ''hangars.'' Dirigible airships, however, can remain in the air much longer than aeroplanes and can travel, in one trip, for a greater distance.

THE STOPPING OF THE MOTOR MAKES THE STOPPING OF THE STORY.

The main distinction to bear in mind between airships and aeroplanes, is that, with airships, the craft merely floats in the air when the motor stops, but with aeroplanes, as soon as anything goes wrong with the motor, the machine begins to descend, because it requires motion for support. Still, the stopping of a motor is not necessarily a fatal accident, as aviators may, and often have, made wonderful glides to earth from great heights, by actually using the air, not as a medium to fall through, but as a means of safe and sure support.

CHAPTER LXV.

Moving Pictures.

CATCHING MOTION ON THE WING.

IN the year 1887, the idea occurred to Thomas A. Edison that it was possible to devise an instrument which would do for the eye what the phonograph does for the ear, and that, by a combination of the two, motion and sound could be recorded and reproduced simultaneously. This was the practical origin of what we know as the ''moving picture machine,'' which, without phonograph attachment, is used for casting upon a white sheet or screen, a series of instantaneous photographs of a moving scene, in rapid succession, so as to reproduce the scene as it was photographed, with every movement, every change of facial expression, recorded exactly as in the original, and all figures life-size. The title of the moving picture machine was the kinetoscope or cinematograph, but there have since been patented about one hundred and twenty machines fundamentally similar in principle, under as many different names.

THE WHEEL-OF-LIFE AND WHAT IT LED TO.

Several inventions contributed to the success of Edison's kinetoscope. The germ of the idea was a little toy called the zoetrope or ''wheel-of-life,'' which became popular about 1860. This was a contrivance consisting of a cylinder ten inches wide, open at the top, around the lower and interior rim of which a series of related pictures was placed, representing any given phase of life susceptible of swift and continuous motion. The cylinder was rotated and the eye of the spectator being directed to the narrow and vertical slits on the outer surface of the cylinder, saw a series of pictures of men or horses going through spasmodic antics. The failure of these successive images to blend into an illusive action picture, set Mr. Edison to work to perfect it.

He adapted to the zoetrope the dry-plate process of instantaneous photography discovered by Maddox in 1878. The ribbon film was not introduced until ten years later, and the use of this was vastly aided in 1890 by the invention of the Friese-Greene and Evans camera, capable of making ten exposures per second. It was in 1893-94 that Edison first showed the kinetoscope. That was at the World's Fair at Chicago. He exhibited pictures the size of a postage stamp carried on a film behind which was a small electric lamp. The observer viewed the pictures through a slit in the rapidly rotating shutter, each picture being visible but the fraction of a second and thus giving the effect of continuous motion. The first machine for projecting motion pictures by a lantern upon a screen was introduced in 1895 by Lumiere, it is said; but Edison also used such a machine at about the same time.

THE LENS AND THE FILM.

In explaining how a kinetoscope works, one must begin with the most essential feature, the film. This is made with a special camera, which is trained upon the moving scene. In this camera the sensitive film is made to move at a determined rate of speed, across the focal plane of a lens of wide aperture and short focus, admitting the maximum of light. This forward motion of the film is not continuous, but is broken by a series of short, instantaneous pauses, about sixteen or eighteen per second, during which time about a foot of the film passes, and, exactly in unison with these pauses, a shutter makes exposures of the film to the light that strikes it through the lens. This negative film, one hundred and fifty, two hundred and fifty, or five hundred feet or more in length, with its series of impressions of the moving scene, is developed in the usual way, and a positive film is printed from it. It is this positive film which is used in the kinetoscope. The finished positive film is one and one-eighth inches wide having the series of pictures close together along the center, each one inch wide and three-quarters of an inch high. Along each side of the series of pictures is a margin punched with a row of holes, these being afterwards used by the mechanism of the kinetoscope to propel the film forward.

THE MAKING OF "RECORDS."

The making of the "record," as the long picture-film is called, is a most important process. The drama to be photographed is carefully arranged. The play may be written by some famous playwright, like Paul Hervieu or Edmond Rostand. The public has grown critical of moving-picture "shows," which, like the regular drama, often fail to "draw." The characters learn a prescribed dialogue, though this will not be reproduced by any phonographic instrument; it being intended only to hold the story and play together while the scenes are being photographed. The best stagecraft is employed in preparing the stage-setting, costumes and action, because all will be reproduced with photographic exactness. If the setting is arranged on a stage or in a studio, the scenery is painted black, white, and gray. Electric lights of fifty thousand to one hundred thousand candle power are necessary for the photographic process. If the scene is arranged out of doors in a natural setting, the same care is required to produce a life-like performance.

REAL ACTORS AND DUMMIES.

The play is rehearsed, and the process is timed. Too long a film bores an audience. ''Keep on the move'' is the rule of the players. The camera is set up, focussed, and the lens ''stopped down.'' The film, wound on the big spool, is placed in position in the mechanism in much the same way as a sewing-machine is threaded. Then on signal the camera-man, with hand on the crank, begins to turn the machinery the instant the play begins, and the revolving mechanism unrolls the long film as the act progresses. If a film is unrolled for half an hour, a series of twenty-eight thousand eight hundred pictorial records of the event are photographed. The total length of such a film is two thousand one hundred feet. If the scenes are out of doors, an interval of days may elapse between them, to enable the players to prepare details and reach the place where the play is to continue. To make a record showing freak escapades, the camera is stopped in the middle of the scene, and a dummy is substituted for the live actor, thus making it possible to show the character in the picture falling down a precipice or being knocked over by an automobile.

The film-maker usually sells his films to a middleman, who rents them out to the theaters for a certain number of days, thus enabling the theater to change its bill as often as required.

THROWING THE LIGHT.

Now we come to the use of the film in the kinetoscope. In this machine, the magic lantern is the type used. The lens is placed well forward, while the mechanism of the machine is between the lens and the box containing the arc-light. This light, which has a direct current, is deemed more steady for this purpose than one made by an alternating current. If the apparatus is placed near the screen, and the pictures are therefore to be smaller, less illumination is needed, and the oxyhydrogen light will serve the purpose.

FEEDING THE MACHINE.

How does the long film feed the machine? It is already wound around the spindle of the big spool or reel, which has sides a foot in diameter. This spool is set above the machine, and the film passed over a wheel with teeth at each end which exactly fit the holes along the margin of the film, while a roller presses against the film to prevent its getting out of place. As one turns the operating crank by hand at the side of the machine (or starts it by electric-power attachment), the film passes downward across the opening where the light shines from the lantern, and around another wheel with teeth on either side which also enter the holes on the margin of the film. This wheel is moved around by an arm (an ''eccentric'') which acts by short jerks, stopping the film for the smallest fraction of a second as each little picture by turn comes before the light, while at the same instant the shutter opens to allow the light to pass through the picture. The film passes on and is wound up on a spool below like the one above.

The film is now manufactured of a celluloid which is fire-proofed to overcome the dangers of burning the highly inflammable material of which the film was formerly made. To prevent this happening, there is also a shutter at the opening where the light and heat are, which closes the instant the speed of the rapidly-running ribbon-film is reduced, the speed itself being a protection.

MILLIONS OF PATRONS A DAY.

So popular is the moving picture show that, it is said, Edison was obtaining in 1911 about $10,000 a week in royalties on his patents connected with the kinetoscope; and a film manufacturing concern in Paris is said to pay ninety per cent in dividends on its capital. There are only about three hundred firms in the world interested in film-making, however, as the work is expensive. England in 1911 had over four thousand moving picture theaters, patronized by more than three million people daily, and the United States had over three times as many. About $100,000,000 is invested in the business in the United States.

HOW THE WHOLE WORLD COMES INTO VIEW.

All sorts of plays and subjects of educational interest are reproduced. Farce of the ‘‘knock about’’ variety has proved the most popular, especially when associated with stage trickery. By reversing sections of the film and by changes in the stage properties amazing performances can be produced. Travel scenes, scientific subjects treated in a popular way, and those depicting manufactures and industries are also very popular. Variety is necessary for the success of the moving-picture theater. Pantomime, romantic stories, fairy tales, and great dramas like ‘‘The Burning of Rome’’ are shown. Motion pictures of the coronation of King George V were shown in New York in natural colors two weeks after the event. This exhibition included sound effects, and the scenes were the review of troops by the King and Emperor William, the naval review at Spithead, lawn fêtes and other incidents. The combination of sounds with scenes in natural colors is being perfected by Edison and other inventors.

Moving pictures are now a great educational force. The lion stalking its prey, the interior of an ant’s nest, the dangerous germ-carrying powers of the house-fly, and the blood flowing in the veins of a frog, showing germs attacking the corpuscles, are some of the wonders shown. Shackleton brought back the life of the South Polar regions in moving picture films; Roosevelt, too, brought films from Africa. The camera has been set up in front of a locomotive and passing scenes shown, and Niagara's majestic action has been photographed.

Lectures illustrated with the kinetoscope, have been given by various specialists as part of education and social betterment work. Churches, schools, business concerns, political organizations, and civic exhibitions all employ moving pictures to present the evidence on which to base their teachings, and the United States Navy uses them to show to prospective recruits the life of the Blue Jackets. Glimpses of wild birds in their haunts, the formation of drops of water, various chemical combinations, fruit growing, logging operations, views from the Eiffel Tower and from airships, and a great many other subjects are shown by the various interests involved. The whole world is being explored by scientists and travelers with moving picture cameras to obtain films that depict events occurring in every country and every clime.

CHAPTER LXVI.

Illuminating Gas.

THERE are two kinds of gas manufactured for illuminating most places; one is called coal gas and the other water gas. As a rule, a mixture of these two gases is sent out, but many towns have only one or the other, as the case may be.

Coal gas is made from soft or bituminous coal, while water gas is made from hard coal or coke together with steam and petroleum oil. Where soft coal is cheapest, so-called coal gas is made, but where oil is comparatively cheap, the product is water gas.

THE MAKING OF COAL GAS.

In making coal gas, the coal is put into long closed, cylindrical, fireclay vessels which are fitted into a furnace in such a way that they can be heated uniformly. These cylindrical vessels are called retorts, and are usually about nine feet long and D-shaped—that is, the bottom is flat and the top arched. Each retort is closed with a mouth-piece having a pipe to carry off the gas as it is made. If we open the pipe leading from the retort and apply a flame to it; it will burn in the same manner as ordinary gas burns in the house. This is practically all there is to the manufacture of coal gas; but the actual practice is much more complicated.

PURIFYING THE PRODUCT.

As the gas comes from the retort it contains much smoke and is made to pass, first, through a water seal or trap which is called a hydraulic main. The pipe from the retort dips into this seal of water and the hydraulic main carries the gas through to a cooling apparatus called a ''scrubber,'' or tar-extractor, which takes out the greater part of the smoke which we should see issuing from the retort if we opened it. After taking out the tar by simple cooling, the gas is usually washed with some kind of oil or tar, to take out more of the smoke. Simple cooling is not sufficient to remove all the smoke. The next step is to wash out from the coal gas the ammonia which it contains, and, in some cases, ammonium cyanide as well. This is done by allowing the gas to pass over some material wet with water. Ammonia compounds are very soluble in water, and when the gas comes in contact with these wetted surfaces, ammonia compounds are rapidly absorbed and dissolve in the water. After the ammonia is washed out, the gas is purified from the sulphur compounds, which would give it a very bad odor if they were left in; and, worse yet, they would corrode all the gas fixtures in our houses. For this sulphur purification, the gas is passed through boxes containing iron rust or iron oxide. This has the property of combining with the sulphur impurities, hydrogen sulphide being the most important. After going through the oxide of iron boxes, the gas passes to a large gas meter, and finally into the gas holder, erroneously called a ''gasometer'' (it does not measure the gas, it only holds it, and the word gasometer means a gas measure). From the gas holder it passes into the pipes along the streets and through the smaller pipes into our houses to be burned as we need it.

HOW WATER GAS IS MADE.

What has been said in regard to coal gas is only changed partially in the manufacture of water gas, although the materials used are of a different character. In water gas making, the first step is the production of what is called blue gas (because it burns with a blue flame) having no illuminating power. This is made by using tall cylinders filled with hard coal or coke, very much like enormous cylinder stoves as used in houses. These large generators, as they are called, contain from five to twenty tons of hard coal or coke, according to the size of the gas plant. The coal or coke is ignited in the same manner that we start a fire in a cylindrical stove in the house. The lower part of the cylinders are tight except where a pipe enters which carries air for the combustion. That is, the lower part of the generator has a blast of air that makes the coke or hard coal very hot. This pipe has a valve which can be tightly shut, and, after raising the temperature of the fuel to the proper point, a white heat, the air is shut off, then steam is blown through another pipe underneath the grate bars, and, as it passes through the mass of white hot coal or coke, it is converted into a gas which consists of a mixture of hydrogen and carbon monoxide, commonly called carbonic oxide. These two gases pass from the top of the fuel chamber, into another apparatus where they are mixed with the vapor of oil. As soon as the fuel begins to cool, the steam is shut off and air is again applied to raise the fuel to white heat. We thus have in the generator changes from a blast of air to a blast of steam, according to whether we desire to heat the fuel or make gas.

When we are blowing the fuel with air, the products of combustion are forced into another cylinder, of about the same height as the one containing the coal, but filled with fire-brick, and the air, in its passage through the second cylinder, transfers its heat to the fire-brick, raising the brick to a high temperature that is recognized by its bright, orange-yellow color. If we put oil into the hot fire-brick at this temperature, it is decomposed into gas, called oil gas. Then, if the air is shut off from the generator, the steam carries through from the fire the blue gas or mixture of hydrogen and carbon monoxide which is formed in the generator; and when the oil is introduced, the blue gas mingles with the oil gas, and the mixture passes on through the hot fire-brick, giving what is called carbureted water gas. After permeating the fire-brick, the gas is put through a seal corresponding to the hydraulic main mentioned in making coal gas, but as this contains a current of water, it is called a wash box, and not a hydraulic main. On passing the wash box the gas contains smoke and other impurities corresponding to those in the products of soft coal, only the smoke is very much more difficult to condense. The same operations of cooling and washing are performed on this gas as with coal gas, only one additional piece of apparatus called a ''shavings scrubber'' is used to get out the last particles of tar. It consists of a cylinder filled with dry wood shavings or chips, a kind of filter which prevents the tar from getting into the purifiers and holder and thence into the pipe.

NAMES FOR SOME OF THE APPARATUS.

Water gas also contains sulphur compounds in the same manner that coal gas does, and the same kind of ''purifiers''—boxes of oxide of iron—are used in this case also, for purifying gas. Finally the gas is passed through a large station meter, and then into the ''holder,'' to be sent to the consumer. In the case of coal gas it has been stated that the coal is heated in cylinders, often six, eight, or even ten in number, and the gas driven out of it by heat. This cluster of cylinders is called a ''bench.'' In the case of the water gas apparatus, the large furnace containing the coke or hard coal is called a ''generator;'' the fire-brick apparatus is a ''carbureter;'' and the fire-brick cylinder which follows the carbureter is called a ''superheater.'' This is used to convert as much of the vapor of the oil as possible into gas by a longer contact with the hot fire-brick surfaces.

DIFFERENT KINDS OF GASES.

The gases produced by these methods, coal gas or water gas, as the case may be, consist of mixtures of the following gases: carbon dioxide or carbonic acid, illuminating hydrocarbons, carbon monoxide (carbonic oxide), hydrogen, marsh gas and small quantities of nitrogen and oxygen (air from leaks in the apparatus). The difference between the two gases is not of much importance, as far as their illuminating value is concerned, but, owing to the fact that water gas contains a larger proportion of carbon monoxide and also a larger proportion of illuminating hydrocarbons, it has a greater density than coal gas. The water gas contains about four times as much carbon monoxide and three times as much illuminating hydrocarbon as coal gas.

HOW GAS IS MEASURED AND SOLD.

Illuminating gas is sold usually by candle power. This means that when the gas is burned in a certain gas burner at the rate of five cubic feet per hour, and its light is measured against a standard or spermaceti candle burning two grains per minute, the number of times that such a flame is stronger than the candle flame, is called the candle-power. In practice, this is actually measured in every large city of importance; and "20 C. P." or "25 C. P.," as the case may be, means that a flame burning five cubic feet of gas per hour is equivalent in light value to twenty or twenty-five spermaceti candles burning at one time.

Gas is also sold in some cities in Europe and in the United States by what is called heat units, or British Thermal Unit ("B. T. U."). This means that if, when one cubic foot of gas is burned, and all the heat which it gives out is caught in water, it raises the temperature of one pound of water one degree on a Fahrenheit thermometer, it has "one B. T. U." In other words, we say that the "British Thermal Unit" is the amount of heat that will raise one pound of water one degree Fahrenheit.

LAWS FIX THE STANDARD.

The laws in every civilized country determine the standard and quality of the gas furnished to the consumer. As a rule, a gas of twenty candle-power is supplied and must be practically free from sulphur and ammonia. In some localities, it must also have a definite heating value, that is to say, one cubic foot of gas must give a certain number of "B. T. U." when burned.

The gas supplied to most cities would raise one pound of water from five hundred to six hundred degrees, Fahrenheit; but, since water boils at two hundred and twelve degrees, the formula would not be expressed exactly that way; so it is said that one cubic foot of gas will raise five hundred to six hundred pounds of water one degree Fahrenheit.

USES FOR GAS.

Gas is now indispensable in all large cities, not only for illumination, but for fuel, and by far the larger proportion of the day output is used for cooking. In many cities where there are small manufactories, large quantities of gas are also used in gas engines and for other sources of power.

CHAPTER LXVII.

Electric Lighting.

ARC LAMPS.

THE electric lights that are used in practical illumination are mainly of two general types, the arc lamp and the incandescent lamp. In the arc lamp the electric current is caused to pass across a small gap between two carbon rods placed end to end. As the current meets considerable resistance at the gap, great heat is generated there, so that the ends of the carbon rods become white-hot and shine with an intensely brilliant light. The carbons, as they are exposed to this fierce heat in contact with the air, become slowly consumed, one of them burning away approximately twice as fast as the other, when the lights are used on a direct-current circuit. As the wasting away of the carbons would soon cause their ends to be too far apart to allow the continued passage of the current, an automatic mechanism is provided by which they are continually caused to approach each other as they become consumed, and to remain always at the right distance for the effective operation of the lamp. Arc lights are particularly useful for street illumination, and also for the lighting of large halls; but they are too powerful for use in the illumination of dwellings. Small arc lamps could be made, but they would be far less convenient than the incandescent lamps that are so commonly employed for indoor work.

INCANDESCENT LAMPS.

The incandescent electric lamp consists of a filament or wire of some sort, enclosed in an air-tight bulb of glass. An electric current is sent through the filament, which is thereby raised to a white heat, so that it emits a soft and brilliant light. In most of the commercial lamps the filament is made of carbon, and the air is removed from the bulb by means of an efficient air pump, this being necessary because the carbon filament would at once take fire and be entirely consumed, if any sensible amount of air were present.

TUNGSTEN AND TANTALUM LAMPS.

Substances other than carbon have been tried in the manufacture of the filaments, and successful results have been obtained by the use of wires of tungsten and tantalum, so that lamps using these metals in the place of carbon are now becoming more or less common. They have the advantage, over carbon-filament lamps, of giving a greater amount of light for a given consumption of electrical energy, but the metal filaments are somewhat brittle, and lamps in which they are used therefore have to be handled with greater care.

SEALING IN THE CONDUCTORS.

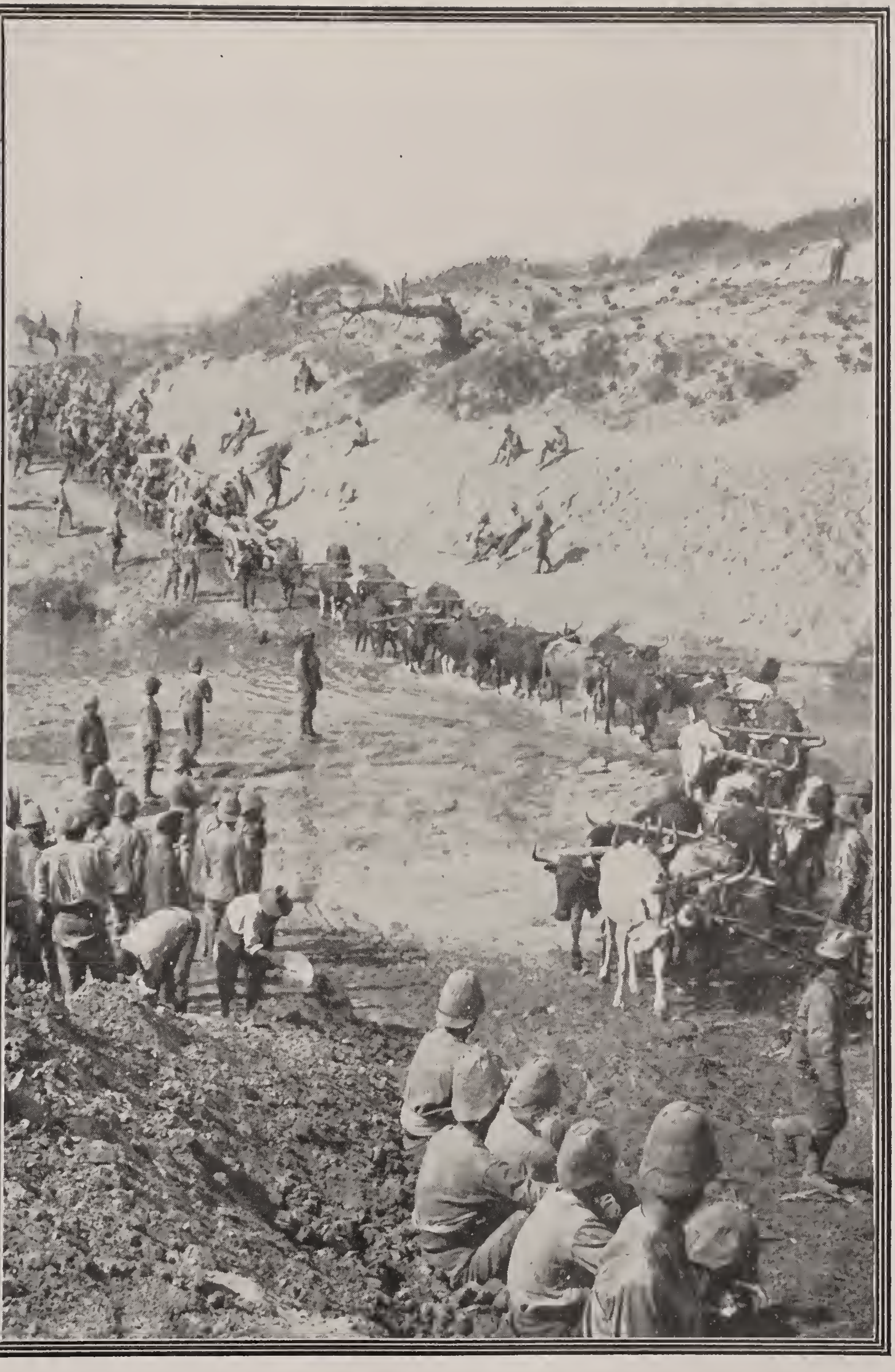
In the manufacture of incandescent lamps it is essential to obtain a perfectly air-tight joint where the conducting wires pass through the glass to connect with the ends of the filament within. These wires are sealed in, by melting the glass around them. It is important, however, to have the metal that is sealed into the glass expand, by heat, precisely as much as the glass itself does; for otherwise a small crack-like space will form around the wire after the lamp has been heated and cooled a number of times by use, and air will then enter the bulb, gradually destroying the vacuum, and hence also leading to the destruction of the filament, especially when that is of carbon. Platinum is used almost exclusively for sealing into the glass, because it is the only metal yet found which is entirely satisfactory for the purpose. As it is exceedingly expensive, the makers use as little of it as possible,—just enough, in fact, to pass through the glass and be soldered at either end to wires of some cheaper metal, such as copper. Alloys have been prepared with substantially the same expansive properties as glass, but none of these has proved equal to platinum, in practice, for sealing into the bulb.

MERCURY VAPOR LAMPS.

The mercury vapor lamp consists of a long glass tube, usually straight, which is freed from air as perfectly as possible, and contains a small quantity of liquid mercury. An electrode is also sealed into the tube at each end, for the entrance and exit of the electric current. Mercury will evaporate to some extent, even at ordinary temperatures; and hence the tube, although freed from air, is not really vacuous, but is filled with highly attenuated vapor of mercury. When a lamp of this type is in operation, the electric current traverses the mercury vapor, which is thereby caused to glow with a brilliant light. Mercury vapor lamps may be operated satisfactorily by an electromotive force of from fifty to one hundred volts, and the quantity of light that they give is several times as great as that yielded by ordinary incandescent lamps using the same amount of electrical energy. Unfortunately, however, the light from the mercury vapor lamp contains no red rays, and hence it gives a somewhat ghastly appearance to the objects it illuminates.

THE NERNST LAMP.

In the Nernst electric lamp the current is passed through a small rod or "glower," consisting essentially of the oxides of certain rare meals such as zirconium, thorium, and yttrium, which have the property of shining with exceeding brilliance when sufficiently heated. The Nernst lamp gives a fine light, closely resembling daylight, and it is also quite efficient. It is relatively high in first cost, however, and it is also more or less complicated, because the "glower" will conduct electricity only when it is hot; and it is therefore necessary to include in the lamp a device of some kind to raise the temperature of the "glower" to the proper point, before the lamp will light.



TRANSPORTATION BY OXEN.—Guns and munitions of war being carried on wagons drawn by oxen.

PART VII.

Munitions Used in Warfare.

CHAPTER LXVIII.

Gunpowder.

WHEN AN ARMY WAS BLOWN TO PIECES.

THE earliest use of gunpowder probably dates back to A. D. 421, when Honorus and his brother-in-law Constantine reigned in Ravenna. In those days, war was almost always in progress. The borders of different countries were in dispute and those untamed, semi-civilized people, knowing no other means of settling a dispute than war, perpetrated the most horrible butcheries in calm, cold blood.

One day Libanus, a general under Constantine, came to the emperor and said he had a secret by which he could destroy the enemy without bringing the soldiers into battle. He would not divulge his secret, but begged for a chance to prove what he could do. He was granted his request, and set an explosive powder where he could entrap his opponents. His plan worked so well that he not only destroyed the enemy by blowing them into fragments, but struck terror to the hearts of his own people, who declared that he must have come from the infernal regions, as he possessed such powers of witchery. Princess Placidia, sister of Honorus and wife of Constantine, was so incensed that she immediately declared she would divorce her husband if he ever had anything more to do with the Evil One, and ordered Libanus put to death. This was done, the secret died with him, and the alarming experience so worked upon those simple-minded, superstitious people that gunpowder became a tabooed subject for almost three hundred years.

THE GREEKS BLAZE THE WAY.

In A. D. 717 the Greeks used an explosive powder to project missiles through tubes against the Saracens in defense of Constantinople. Their greatest mistake was not in the construction of the powder but in the missiles thrown. Instead of using lead, as we do now, they employed beaten rocks or earth, which merely flew through the air or flattened out upon the objects they struck. However, the principle of the explosive power of projection was correct, for it is upon their formulæ that all the gunpowder explosives of succeeding centuries have been based.

The prime ingredient was saltpeter, which was mixed with hazelwood and sulphur. This burns with explosive violence, and its power is due to the great volume of highly heated gas set free. If it were burned in a covered vessel, so that the gases could not escape, the pressure would be about forty tons to the square inch.

Charcoal was finally substituted for hazelwood, and this mixture, when exploded, gives off a thick, black smoke, due to the fact that only about half of the substance is consumed. The other half is hurled into the air by the force of the gases. Instantaneous combustion without smoke, that is, combustion that would completely consume the ingredients, has been one of the problems studied ever since the invention of gunpowder. But until something was found to take the place of saltpeter, sulphur, and charcoal, this problem remained unsolved.

FINDING THE EASIEST WAY OUT.

Another question in the early days of explosive powder was to get all the force in one direction, in order to hurl a projectile without losing much of the force of the explosion. As the powder burned and gave off gases, it expanded in all directions at the same time. To overcome this difficulty and get the force behind the load, a powder was finally made in which each tiny grain was the same size, and hexagonal in shape. This fits them very closely together, forming a compact mass, which burns more slowly and gives the gases a chance to expand and start the projectile before actual explosion takes place. When a body is once set in motion, it is then very easy to keep it going, or even to increase its speed. And so the gases having started the gun-load, the easiest way out for the rest of the exploding particles and gases is to follow that load.

POWER EXERTED BOTH BACKWARD AND FORWARD.

The old-fashioned guns used to be accused of "kicking," because, when the powder exploded, the force being nearly equal in all directions, the gun was hurled backward with a jerk nearly as strong as the force that sent the missile forward; but modifying the shape of the grains of powder has nearly overcome all that.

This mixture of chemicals, compressed, treated, and finally forced by tremendous pressure through hexagonal dies and brought out in long strings like spaghetti, then by another machine cut into the exact size, is the secret of our present useful and terribly destructive gunpowder.

FIRE WITHOUT SMOKE.

The invention of smokeless gunpowder, made possible by the invention of gun-cotton, was attended with less superstition than the old form, but not less destruction of life. It is a peculiar fact that, in perfecting almost any great invention, many human lives are sacrified during the experiments.

In 1849, an Austrian general, named Von Lenk, conceived the idea of using gun-cotton in fire arms. He had several large, strong guns made for the purpose, and proceeded to experiment; but gun-cotton is a spiteful thing and doesn't like being tampered with. After causing several disastrous explosions, and thoroughly scaring himself and his associates, the general gave up the attempt and went back to the old smoky powder.

It has required a great deal of study and experiment to obtain an efficient smokeless-powder, but by the use of certain chemicals, called ''restrainers,'' that retard combustion, and others, called ''accelerators,'' that quicken it, the balance is struck and an explosive is made that leaves no visual trace behind.

CHAPTER LXIX.

Gun-Cotton.

A NEW MIXTURE WITH A QUEER NAME.

AWAY back in 1832, an ambitious inventor named Henri Braconnet discovered, quite accidentally, that common starch when mixed with water and cold nitric acid formed an explosive substance. Believing he had made a great discovery, he named the mixture xyloidine, and proceeded to experiment, hoping to put it to practical use. However, as soon as xyloidine became known, other scientists began to study it, and six years later, Pelonze applied the composition to cotton. He found that when cotton was dipped into the acid solution, washed and dried, it became "self-explosive." This was one step more toward practical use, if it could only be controlled so that it wouldn't explode at unexpected moments.

EVERYTHING WITHIN REACH FLIES IN PIECES.

In 1846, another inventor named Schoenbein, of Switzerland, who had also been experimenting with Braconnet's xyloidine, succeeded in completing the formula for the highly explosive gun-cotton we have today. He mixed nitric and sulphuric acids, dipped the cotton into the solution and then thoroughly washed and dried it. After this process the cotton looks the same as before, but, if it is lighted with a match, it burns with a quick, brilliant, almost smokeless flame, completely consuming the cotton and leaving no ashes. If it is fired off by percussion, that is, by a quick, sharp blow, causing heat by friction, it goes off with an instantaneous, violent explosion that destroys not only the cotton, but everything else within reach.

The secret of an explosion is that burning the substance, such as cotton, gives off gases which expand with the heat, and the quicker the burning, the quicker the expansion of gases. In gun-cotton, of course, cotton is only a foundation to hold the acids. An enormous amount of gas is stored up in that particular mixture of acids, and they also burn very quickly. So the quick burning sets free these powerful gases, expanding them instantly to such an extent that they break with violent force. A bullet, shot by gun-cotton explosion, goes at the rate of two hundred miles a minute.

TOO DANGEROUS EVEN TO EXPERIMENT WITH.

Schoenbein's discovery aroused the liveliest interest all over the world. It was believed that a substitute for the old smoky gun-powder had been found. Immediately inventors and scientists of all nations set to work to perfect gun-cotton so that it might be used in firearms. Unfortunately the material was found to be so irregular in action that it was likely to go off at any time without any apparent reason, thus rendering experiments extremely dangerous. Besides, if it could be used in guns, it was likely to explode at the wrong time and destroy the gun. After much effort, during which serious and unexplainable explosions occurred at Vincennes and Bouchet in France, and Faversham in England, the experiments were discontinued, except in Austria. It was believed that the explosive was so rabid and untamable that it could never be used with safety.

An Austrian general, named Von Lenk, continued his experiments, however, believing that the defects were due to imperfect manufacture. He found that foreign matter, such as dirt, caused the irregular action, and improved the process of cleaning the cotton both before and after it was dipped in the acid. This made such a marked improvement that his government built thirty strong batteries for the use of gun-cotton cartridges. These cartridges were made by twisting the fiber into yarns which were braided together. Von Lenk supposed he had the problem solved, when suddenly a great explosion occurred at Simmering, and another at Steinfeld, causing great loss of life. These explosions could not be explained, and Von Lenk finally abandoned his experiments, believing, like the rest, that gun-cotton was an untamable old demon.

SOMETHING FOUND THAT IS NOT QUITE SO TOUCHY.

England had taken so much interest in Von Lenk's encouraging progress that it had granted him a patent, and in 1864 the manufacture of this braided cotton yarn was begun. In 1865 an Englishman named Abel patented an improvement upon the process which finally solved the problem and gave gun-cotton its place among the safe but powerful explosives.

A THOROUGH SYSTEM OF BATHING.

The cotton in its common state is fibrous, and each fiber hollow like a hair. It was necessary, after the acid bath, to wash out every particle of acid as far as possible, and, since the hollow fibers retained some of the chemical, it was impossible, either by washing or wringing, to dispose of it all; so Abel conceived the idea of pulping the cotton or cutting the fibers into such short lengths that the acid could be squeezed out, and the cotton then be molded by pressure into any desired shape. The raw cotton was first thoroughly cleaned by hand picking, washing, and boiling in alkali, drying, and then picking again both by hand and machine. After this thorough bath in acids, it gets another, equally thorough, in water, and then goes to the pulping machine, where it is ground up and squeezed until it seems as if it couldn't have a bit of explosive quality left. After pulping, it is put through another bath, where it is pounded and paddled, and the water frequently changed; then, to make sure it is thoroughly clean, it is treated to another bath in a solution of lime and caustic acid, and what is left of it is ready for molding.

HOW TO FIRE IT OFF.

The first use for gun-cotton was in the form of powder for fire-arms, but it soon developed many uses in other shapes—in naval mines and torpedoes, for instance, and for other military engineering operations. When dry, gun-cotton is exploded by inserting a detonator in the hole in a block of it and firing. Wet gun-cotton is set off by exploding near it some dry gun-cotton. It can be used under water by sending down a charge of dry cotton in a water-proof case and exploding it near the wet charge. Wet gun-cotton can be handled in all safety, even sawed and chiseled into various shapes if kept wet during the process, so that the friction of the tools will not cause heat.

A MATERIAL UNSAFE WHEN "SAFE."

Although years of study and experiment have given us what is considered the safe use of gun-cotton, it still remains a violent, and sometimes surprisingly unmanageable monster. As late as 1875 an unexplainable explosion occurred in England in the manufacturing plant of a company called "The Patent Safe Gun-Cotton Co." Twenty-five people were killed instantly and more than seventy-five were terribly maimed and crippled; and ten brick buildings were wiped completely off the earth.

CHAPTER LXX.

Gatling Guns.

MAKING WAR MORE TERRIBLE.

DR. R. J. GATLING, a physician of Indianapolis, one of the gentlest and kindliest of men, seeing the soldiers returning wounded from battle, early in the Civil War, began to consider how the horrors of war might be alleviated. By making war more terrible, it seemed to him nations would be less willing to resort to arms, and, with this end in view, he devoted himself to the study of ordnance and ballistics.

His inventive mind saw possibilities of development in the multiple firing guns, the first attempt at making which dates back to the early part of the seventeenth century. The Chinese had made small guns as early as 1607, crude in construction, having two parallel barrels reinforced at the breech ends with three hoops, each having a vent, and evidently arranged to fire three shots successively out of each barrel. Dr. Gatling traced the ineffectual efforts of inventors from the seventeenth to the nineteenth centuries to produce rapid-firing guns. When the Civil War began, other inventors besides himself studied the problems of ordnance, and many forms of magazine and repeating rifles, pistols, and machine guns, all more or less effective, were produced; but the gun that he made in 1861 was the best of all. His is a machine gun which can discharge an almost continuous fire of cartridges.

FIRING GUNS BY MACHINERY.

The essential feature of all machine guns is that the loading, extracting of the empty shells, and firing, are all performed, wholly or in part, by machinery. They are fired from tripod mountings or from traveling carriages, and can be transported either by carriage or on muleback.

THREE CLASSES OF MACHINE GUNS.

Machine guns are of three classes: (1) those operated by hand power, electric motor, or any other form of exterior force; (2) the semi-automatic, in which, although the energy of the recoil is partially used to actuate the breech mechanism, each round of ammunition is inserted by hand, and the trigger is pressed for each discharge; (3) the automatic, in which the energy or recoil, or a part of the powder gas pressure, at each discharge, is fully utilized to operate the piece, which forces the rounds continuously while the trigger is pressed. The Gatling and Gardner guns are good examples of the first class. The Colt, Hotchkiss, Yamanouchi, Maxim-Nordenfeldt, and Dawson-Silverman (Vickers) are of the automatic class.

HOW THE GUN GOES ROUND.

The Gatling gun consists of a number, usually ten, of parallel barrels grouped around and secured firmly to a main central shaft, to which is also attached the grooved cartridge carrier and the lock cylinder. Each barrel is provided with its own lock or firing mechanism, independent of the others, but all of them revolve simultaneously with the barrels, carrier, and the inner breech, when the gun is in operation. The rotation of the gun gives a reciprocating motion to the locks, the forward and backward movement being effected by a cam actuated by the turning of the operating crank. In firing, one end of the feed case containing the cartridges is placed in the hopper on top, and the operating crank turned. The cartridges drop one by one into the grooves of the carrier, and are loaded and fired by the forward motion of the locks, which also closes the breech, while the backward motion extracts and expels the empty shells.

WHEN CARTRIDGES JAMMED.

When first invented the Gatling gun was entirely different in principle and action from all other multiple-fire guns, admitting of faster discharges and heavier projectiles. It has passed through some stages of alteration and improvement, mainly in the arrangements of feeding the ammunition. At different elevations the original tin feed-cases worked irregularly, so that the cartridges did not always fall into their positions in the grooves of the carrier, and jamming was of frequent occurrence. Various devices were arranged to obviate this defect. The Bruce feed-case, constructed on the gravity principle, overcame the defect of jamming, but not its irregularity of action at different angles of elevation, and was superseded by the Accles feed-drum. This was a positive feeder, which, rotating with the revolving barrels and lock cylinder, fed the cartridges with perfect regularity at any angle of elevation. It had, however, two serious drawbacks—its weight and the large amount of exposed surface, which, if struck by a single bullet, would put it out of action. In the latest method of feeding employed, the cartridges are attached to long strips of flexible metal and are fed into the openings in the hopper. As the gun is revolved by the operating crank, the projections in the grooves of the carrier act upon the cartridges and force the strips through the hopper, each cartridge being deposited in its proper position in the grooves of the carrier block and the empty strips thrown out to the right.

SPREADING THE BULLETS OVER THE FIELD.

In the latest forms, an automatic traversing arrangement for scattering the bullets is attached, which can be thrown in or out of gear as may be desired, regulating the amplitude of the arc through which the breech is moved so as to spread the bullets over the required front. In the present state of efficiency, the Gatling gun fires at the rate of one thousand two hundred shots per minute, a speed of fire, by separate discharges, not as yet equalled by any other gun.

CHAPTER LXXI.

Modern Warships.

A RACE BETWEEN GUNS AND ARMOR-PLATE.

IN early times sea battles were fought with galleys in which the rowers, slaves, were chained to the seats so that, in case of defeat, there would be no chance of augmenting the enemy's forces by the addition of trained and husky athletes. Attempts were made at different periods to provide some sort of armor protection to the boats by felt, lead or leather; and, in the sixteenth century, it is claimed that a Dutch vessel was partly covered with iron. But, until comparatively recent years, new methods of at-

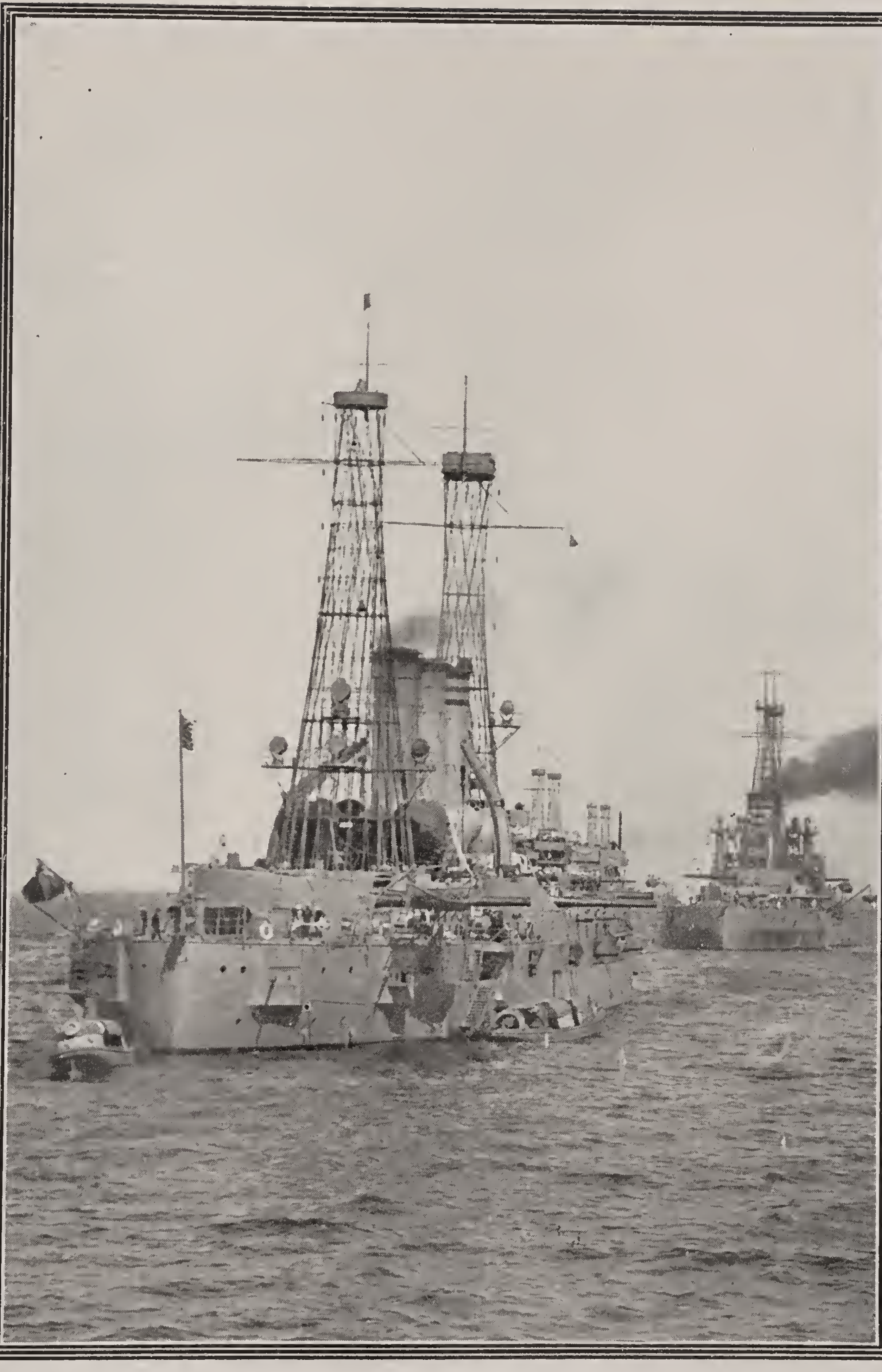
and *Merrimac* and the memorable battle at Hampton Roads. It was undoubtedly the new idea of the revolving turret that saved the day, which compressed the attacking power instead of distributing it, and made it more easily and quickly available than in the stationary broadsides of the *Merrimac.* The smallness of the target also contributed to the *Monitor's* success, in no small degree, as well as the thickness of her armor—eight inches to the *Merrimac's* four; but the armor of neither vessel was pierced. Of course this battle settled the status of the ironclad, especially of the *Monitor* type—a type which still persists in modified form and whose central idea, the revolving turret, has been transferred to the battleship and cruiser.

A PERIOD OF LETHARGY.

During the Civil War a good many other armored boats were built, but after the close of the war naval construction almost entirely ceased for many years. Three sloops of war were built, to be sure, in the early seventies, but they were "unarmored," having only iron hulls. These, with a few left over from war times, marked the lowest ebb in United States naval affairs, when "of the forty-eight so-called ironclads on the navy register, thirty-one can never be of the least use in peace or war." It was a period of strange and unaccountable lethargy.

THE UNITED STATES WAKES UP AND BUILDS CRUISERS.

Then, in 1882, the United States woke up again and a period of warship building began that has placed the country second in the range of naval powers. A recommendation was made that year for constructing three cruisers—a cruiser is a "gunboat" of more than two thousand tons and is built on speed lines—and the *Chicago,* the *Atlanta* and the *Boston* were the answer to the call. They were coal-protected, that is, their armor was, in the main, the coal bunkers which were



AN AMERICAN BATTLESHIP.—The "Minnesota," showing the latticed towers.

placed in such position as to protect the machinery. Predecessors these were of many others, mostly of the ''armored'' and ''protected'' class. The former carry vertical armor, as the name implies, but much less in thickness and amount than that on the battleship. The protected cruiser has a thick steel deck, whose edges incline downward so as to meet the side below the water line. There are also ''auxiliary cruisers''—swift merchant vessels impressed into service in time of war, that act as scouts.

The cruiser must sacrifice armor and armament to speed, which is the first requisite, and yet possess enough of both to give good account of herself if it is necessary. She must also have large capacity for coal and stores.

THE GROWTH OF BATTLESHIPS.

In 1888 the keels of the second-class battleships *Maine*—the ill-fated *Maine*—and the *Texas,* were laid; their side-armor was twelve inches thick. The pioneer first class battleships, the *Indiana,* the *Massachusetts* and the famous *Oregon,* with side-armor of eighteen inches, were begun in 1891. These were of ten thousand tons. Battleships since then have followed in rapid succession, changes and improvements being made as suggested by actual experience, especially the Spanish-American and Russo-Japanese wars, or by practice-maneuvers and long voyages. Giant warships are now built of twenty-eight thousand tons, and plans are proposed for a thirty-one-thousand-ton ship!

CHARACTERISTICS OF THE BATTLESHIP.

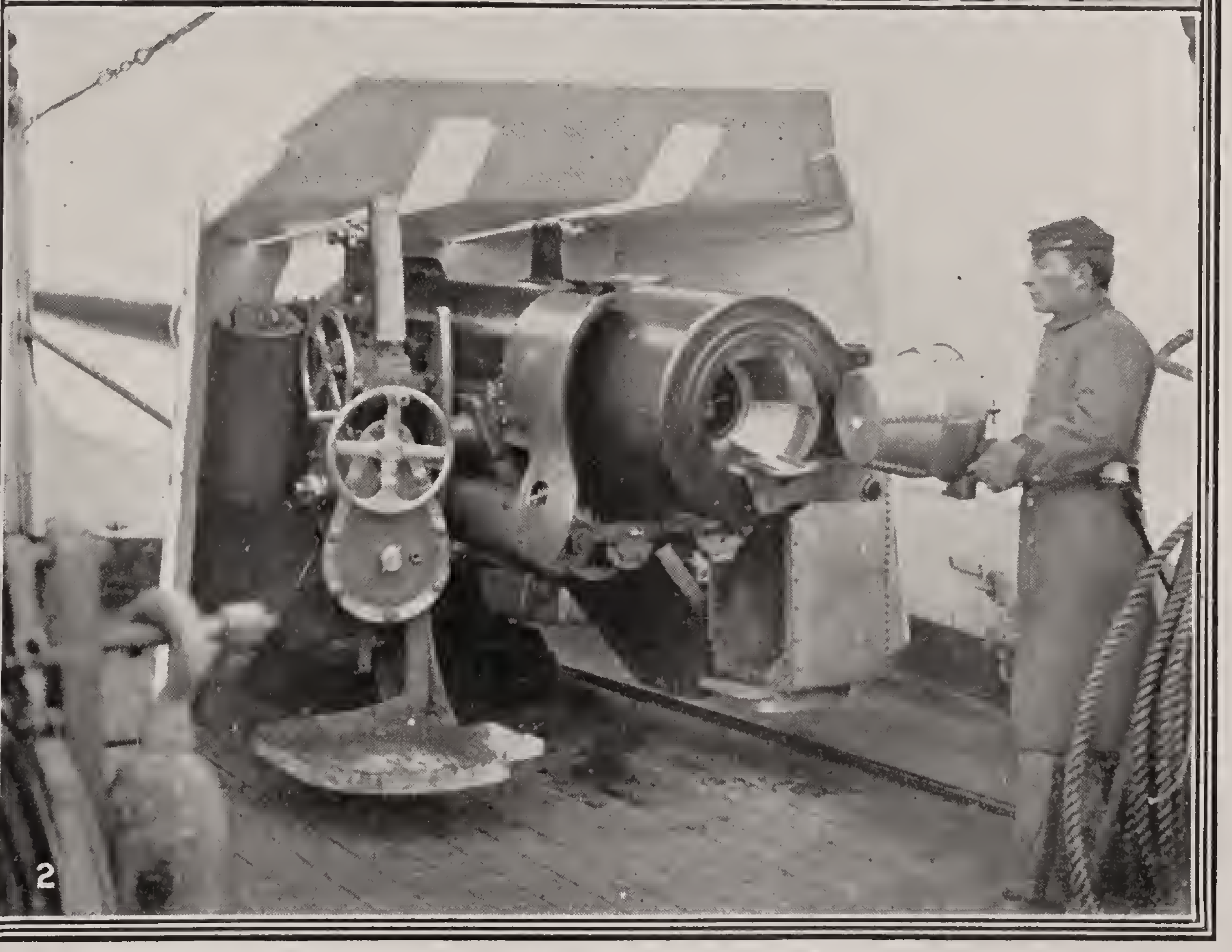
The characteristics of the battleship are large guns and thick armor. Armor used to be placed only amidships; now it runs the whole length, though with reduced thickness at the bow and stern. The ''waterline belt'' of armor, as it is called, extends three or four feet below the surface of the water, and about the same distance above, and rests on an armor-ledge where it meets the "protection deck" at the point of the latter's contact with the ship's side. This deck, which is similar to that on the armored cruiser, but much heavier, is the special bulwark of the vessel's vitals—the boilers, machinery and magazines; for, of course, an injury to any of these would be likely to prove fatal. For further precaution, every opening on this deck is covered with a heavy steel grating.

The guns of a battleship are of two kinds. The main battery comprises the heaviest ten-inch, twelve-inch, or thirteen-inch guns, which fire large shells and armor-piercing projectiles; these are breech-loading and mounted in pairs in revolving barbette turrets, one forward and one aft in the center of the ship, as a rule. In some battleships there are superimposed turrets for eight-inch guns, and there is another pair of eight-inch guns in a turret on each side amidships.

The secondary battery consists of rapid-fire guns, arranged broadside, of smaller caliber than those of the armor-piercing class, and capable of quick action. These are aimed at the personnel of the enemy. The battle of Yalu showed something of their value, but also established the fact that rapid fire alone cannot make a battle decisive.

IMPROVEMENTS IN THE BATTLESHIP.

General improvements in the battleship have been many. Chief among them may be mentioned, a reduction in the size of the largest guns, and increase in the size of the rapid-fire guns; improved quality of armor as well as extension of the surface covered by it; increase in speed and coal capacity; a saving in the weight of machinery; and an increase in the size of the whole vessel.



1. United States sailors practising from the fighting-top.

2. Opening the breach of a big gun on one of Uncle Sam's fighting-machines.

THEN CAME THE DREADNOUGHTS.

In these and other radical points the great *Dreadnought,* launched in England in 1906, inaugurated a new era and, unfortunately, startled the nations into building or rebuilding navies with accelerated speed. It is a British boast that "the *Dreadnought* has made all previous battleships obsolete." Certain it is that the *Super-Dreadnought* quickly followed; then came the *Lion* and *Orion;* and, in the United States, the *Wyoming* is to be a marvel of size and efficiency—the very "latest greatest." "Where is it all to end?" is the universal question.

The *Dreadnought* type is the all-big-gun-one caliber ship, generally turbine driven. Her main battery consists of ten twelve-inch guns, arranged in turrets on the center line. Simplicity of fire control, and hence better arrangement of magazines were gained by the evolution of the idea, and concentration of fire is certainly accomplished; battles are to be fought, say adherents of the *Dreadnought* theory, more and more at long range, and the intermediate gun is to be increasingly used for torpedo defense.

A novel feature in the latest battleships of the United States is the high lattice fire-control towers, which the British say are subject to excessive vibration; they still use tripod masts.

There are very few docks in the world that will take these latest types of warships, and enormous sums must be spent in dredging rivers and harbors to allow of their entrance. These considerations taken in connection with the original cost, nearly or quite $10,000,000, are matters of thoughtful interest.

CHAPTER LXXII.

Torpedoes and Torpedo Boats.

WHAT A TORPEDO IS.

A TORPEDO is a watertight case containing an explosive charge, a fuse, and various mechanisms, designed to act against a ship's bottom or sides. Torpedoes are fixed or moving, the former being now known as submarine mines, and are either self-acting by mechanical means, or governed by operators at a distance. The movable torpedoes are classed as either "controlled" or "uncontrolled," there being several types in each class.

THE TORPEDO IN THE REVOLUTION AND THE CIVIL WAR.

The first mention of anything like this dangerous little waspish device, that goes upon or beneath the water's surface in order to get under something and blow it up, was the trick of an Italian engineer, Gianibelli, in 1575, by which he loaded several small vessels with gunpowder, floated them under a bridge at Antwerp and blew it up, the gunpowder being exploded at the right time by clock-work. The first inventor to use torpedoes against ships was an American, Captain David Bushnell, who, in 1776, attempted to destroy, with a torpedo, Lord Howe's flagship in New York harbor. After him Robert Fulton tried his hand, and with twenty pounds of gunpowder placed in a mine blew up a small vessel at Brest; this was several years before the more peaceful voyage of the *Clermont*. During the Civil War the use of the submarine mine was greatly extended, and twenty-eight vessels were injured or destroyed by this means, the most notable exploit being the destruction of the iron-clad *Albemarle,* by Lieutenant W. B. Cushing, in 1864.

NOT WAITING FOR A VESSEL TO BE BLOWN UP.

It was during this war that the first serious attempt was made to carry or send a torpedo from place to place for the purpose of exploding it, not waiting for a vessel to come along and take the chances of being blown up. It was in 1862 that the spar-torpedo was contrived—a case containing the explosive being fastened to the end of a spar that had been fitted to a steam launch. It was somewhat of a drawback that the launch usually filled with water after the explosion, which was quite likely to put a damper on the enthusiasm of the operators, but the idea of the movable torpedo was there in all its essential features, only waiting to be developed a few years later. In 1867, an Austrian navy officer, Captain Whitehead, succeeded in constructing the "Whitehead torpedo," of the "automobile" or "fish" type, as it is called, which, wonderfully improved of course, as the "Schwartzkoff," or its equivalent, is now employed by all naval powers.

A MOST DELICATE AND COMPLICATED MECHANISM.

The first torpedo traveled six or seven knots an hour and, within two hundred yards was fairly reliable—but not more than "fairly." Now one travels thirty or forty knots an hour for half a mile, but can be set to go much slower and farther; and the accuracy of its aim is so true that it will hit almost exactly the spot desired.

The "Whitehead" is a cylindrical steel flask about sixteen feet long and eighteen inches in diameter, with a pointed or conical, nose-like head of phosphor-bronze, and a metal case; the charge of gun-cotton connecting with the detonating primer, which contains fulminate of mercury and a percussion cap, are in the head, while the case is fairly alive with mechanism of tiny engines, whirling propellers and gyroscopic guiding apparatus, so complicated and delicate that only those trained to the service can handle it. The motive power is compressed air, with which the flask is charged at a pressure of fifteen hundred pounds. The propelling and guiding mechanism can be adjusted so nicely as not only to control all movements but check the projectile at any given moment and raise, lower, or sink it, as desired. Thus the terrible little demon, once released from its tube goes on its mission of death with a pitiless, relentless, almost human intelligence.

Successful experiments have recently been made with an "aerial" torpedo, which is discharged through the air like a rocket, doing deadly execution by impact, at the distance of a mile, or being exploded in mid-air, as desired. Electrical torpedoes are also used, being steered by electricity and operated from ship or land, the torpedo unreeling its coil of wire as it rushes on its course, and thus having its battery or dynamo at all times under the control of an officer.

THE TORPEDO RECONSTRUCTING THE NAVY.

The torpedo has been found so effective in modern warfare, especially since the havoc it wrought in the hands of the Japanese in their war with Russia, that the navies of the world are being reconstructed with a view to resisting, or in turn, augmenting its devastating powers. Not only are torpedo boats and torpedo-boat destroyers being built at a rate never before equalled, but new types of battleships are being evolved to meet the new dangers. As success depended very largely, before submarines came into play, upon the ability of a boat to approach its enemy stealthily and rapidly to within striking distance, a form of vessel was constructed which combined great speed and ease of manipulation and having such shape and size as to offer the least possible target to the enemy.

FROM THE LITTLE STEAM LAUNCH TO THE GREAT DESTROYERS.

The earliest torpedo boat was an ordinary steam cutter, or pinnace, fitted with a spar-torpedo. This was the kind used by Lieutenant Cushing. When the ''Whitehead torpedo'' was invented, a cradle was attached to each side of the vessel for carrying it. The first boat built solely for torpedo use was constructed in 1873; she had the modest length of fifty-seven feet and the moderate speed of nearly fifteen knots an hour. Now the great torpedo-boat destroyers are over two hundred feet in length, and have a speed of thirty knots an hour.

The torpedo boat was developed into the torpedo-boat destroyer, about 1885. Hitherto half of the torpedo flotilla of any nation was used for firing torpedoes and the other half for resisting attack. But as the speeds would be about equal, it was found that neither class could decrease the range of the other when attacking or escaping. So a vessel was added to the British navy, in the year mentioned, with twin screws, more power and higher sea-speed than any other torpedo boats, and was so successful that the *Sea Serpent* was launched a year later, which, in its time, was a famous war vessel. She was not called a ''destroyer,'' for that splendid fighting name had not yet been employed, but an ''exaggerated torpedo boat.'' The ''Rattlesnakes'' or ''torpedo catchers'' were then in fashion, but the ''destroyers,'' as some poetically inventive genius soon called them, are a ''survival of the fittest,'' and now fill a large place in naval equipment.

A RATHER DISCONCERTING DANGER.

A curious danger was encountered when the destroyer began to develop speed, which was that, when the torpedo was fired from the bow gun, the boat showed an alarming tendency to overtake the weapon, which would have been a case of being "hoist with its own petard," and might have been rather disconcerting to the attacking party. So a method was found to make the torpedo "step lively" by heating the compressed air, which increased its energy to such an extent that the torpedo kept ahead of its own guns by reaching a speed of thirty-eight to forty-three knots an hour.

A NEW AND EFFECTIVE DESTROYER.

An entirely new type of destroyer has lately been invented which carries its war head and mechanism in a suspended cigar-shaped hull below the water line and therefore out of reach of an enemy's projectiles. The upper hull, being filled with cellulose, is unsinkable. In attacking, the boat is driven at its full speed of eighteen knots, and, when within striking distance, the men, locking the rudder, jump overboard, leaving the boat to explode its charge of a thousand pounds of gun-cotton by bodily ramming the enemy's ship. Fifty vessels of this type could be built for the price of two or three destroyers, and give the navy possessing them a marked advantage over its rivals.

CHAPTER LXXIII.

Submarines.

BOATS MADE NOT FOR TRAVEL, BUT FOR WAR.

INVENTORS in nearly all the leading nations have tried to make a boat that can explore the bottom of the sea. But the successful submarine boats are not planned for scientific study of pearl oysters, corals, sponges, and sunken ships; they are made for war. The tactical value of the different types of submarines vary considerably in different countries. Some are for sea-going, some for coast-defense, some for harbor-defense. The endeavor now is to devise some plan of using these boats to tow into position and plant lines of mines across the enemy's path, at the mouth of a fortified harbor. This might be accomplished by dropping the submarine overboard from a swift scoutship, at night or during a fog, at a point near the channel leading to the harbor, from which position the vessel carrying it could retreat in safety, leaving the submarine to sink beneath the surface and work unseen at placing the mines. It is planned to use the submarine, not only to discover the enemy's mines, but also to rake the sea-bottom with a cable and drag the mines out of the way. For coast and harbor defense, the submarine boat can be used as a look-out and signal-station, the man in the conning tower with glasses studying the movements of the enemy's ships, dropping below the surface while he sends a cable dispatch or wireless to the shore. Submarine signals can be transmitted with water as a medium at a speed of four thousand seven hundred and fifty feet per second.

FROM ALEXANDER THE GREAT TO THE AMERICAN REVOLUTION.

Some of the early attempts at making submarines though unsuccessful were instructive to inventors. The first form was the diving bell, used as early as the time of Alexander the Great. Borelli, in 1680, suggested the use of water (since successfully tried) for ballast, to preserve balance and adjust the submergence. The first practical submarine was made by David Bushnell about 1775, and his was the earliest to be used in actual warfare. The operator, Sergeant Lee, was able to get underneath the English man-of-war *Ramilles* off New London, Conn., during the Revolution, and was only prevented from blowing her up by his inability to drive the attacking screw through her copper sheathing.

FROM THE REVOLUTION TO THE CIVIL WAR.

Robert Fulton, about 1800, made even better submarines than Bushnell. He used a steam-driven motor instead of foot power. A French boat called the *Plongeur* was the first to use compressed air as a motive power. The Confederates in the Civil War were very successful makers of mines and half-submerged gun boats. The French produced the *Goubet,* which had a bronze hull, pointed at both ends, and carried a crew of two men seated back to back in the conning tower.

THE HOLLAND SUBMARINE IN THE UNITED STATES.

J. P. Holland, of Paterson, N. J., won the favor of the United States government in 1895 by his design for a submarine after the government experts had studied the rival claims of inventors for years. This submarine and others rely solely on their torpedoes for offensive power. In 1900 this country bought seven Holland submarines named the *Adder, Porpoise, Shark, Grampus, Mocassin, Pike,* and *Plunger*. These boats have one hundred and twenty tons displacement; length, sixty-three feet, four inches; beam, eleven feet, nine inches, and depth, eleven feet, nine inches. A flat deck on top, thirty-one feet long, is used when the boats are on the surface. They are equipped with four-cylinder gas engines for surface propulsion, and electric motors for use when submerged. A test of submarines was held off Newport by the United States Navy in 1907, as a result of which the Secretary of the Navy bought the *Octopus,* a submarine of the Holland type, followed by three others of the same kind and again three of larger size. The *Octopus* showed a maximum speed of eleven and six-tenths knots, with the top of the conning tower ten feet below the surface. The mean speed was ten and three-hundredths knots, exceeding by one and five-tenths knots the fastest previous performance of any submarine native or foreign. She was submerged in thirty feet of water for twenty-four hours, and could have remained under for two or three days longer.

SUBMARINES OF OTHER NATIONS.

The success of the Holland boat inspired England and other naval powers to build vessels of a similar type. Now England has more than sixty submarines. Two built in 1910-11 have a displacement of about eight hundred tons each; length, one hundred and seventy-six feet; and maximum breadth, twenty-three feet. Next to England, France in 1911 had the largest submarine flotilla, with fifty-one in commission, and forty-one under construction. France was the first to develop the ''submersible'' boat, which resembles torpedo boats of the ordinary type, and are intended to cruise on the surface. Inside the outer hull is a cigar-shaped submarine. The space between the hulls is mainly used for ballast and submerging tanks. Some of the latest have six hundred and thirty to eight hundred and ten tons displacement, with a speed of ten knots submerged, fifteen knots on the surface, and a radius of action of two thousand five hundred miles. One of these, the *Lake,* built for commercial diving operations, has air-locks for exits, where a diver can leave the boat when it is submerged. Norway has a new submersible, the *Kobben,* one hundred and twenty-nine feet long, with a submerged displacement of two hundred and eighty tons; its two hulls withstand a water pressure equivalent to a sea depth of two hundred and ninety-five feet; it has stood a two-hour test at a depth of one hundred and sixty-four feet.

EQUIPMENT OF THE MODERN SUBMARINE.

In recent years, larger boats are being built. These give rooms for men, fuel, machinery, and other equipment, as well as better speed. The boats of the submersible type have the better sea-going qualities. Gasoline or other vapor engines, with twin screws for propulsion, and electric motors and storage batteries when submerged are the favored motive powers. Conning towers are high enough to give a good outlook. A camera called the periscope makes a visual record of surroundings. Flasks of oxylithic powder purify the air by absorbing the carbonic acid gas of respiration and restoring oxygen.

PART VIII.

The Story of Polar Exploration.

CHAPTER LXXIV.

North Polar Exploration.

IDEAL EXPLORERS HAD ONLY THE SPIRIT OF ADVENTURE.

SPREAD over the polar ends of our swiftly revolving planet is an icy mantle left there as a heritage from the days of the glacial period. Covered with darkness in the winter, and swept by freezing storms, its great expanse of territory remained unexplored, and unconquered. For many hundred years this mysterious region of long dark winters and summers of continual light has had a subtle attraction for navigators and explorers.

As far back as 330 B. C. a bold Greek navigator, Pytheas of Marseilles, sailing on a voyage of discovery, found an island which he named "Thule," probably from the Greek *Telos* (a goal). He was the first ancient mariner to leave us a written record of Arctic conditions. He found that "during the summer solstice the sun for many days did not go below the horizon." Pytheas was also the first explorer to use the sun's shadow for determining the latitude of a place. His island of Thule was probably Iceland.

Over a thousand years passed without farther record, then came the Vikings, sailing the northern seas just for the love of exploration. They settled Iceland and Greenland and the islands of Orkney, Shetland, and Faroe. Their explorations went as far as Labrador and down the northern coast of America to the limits of Cape Cod.

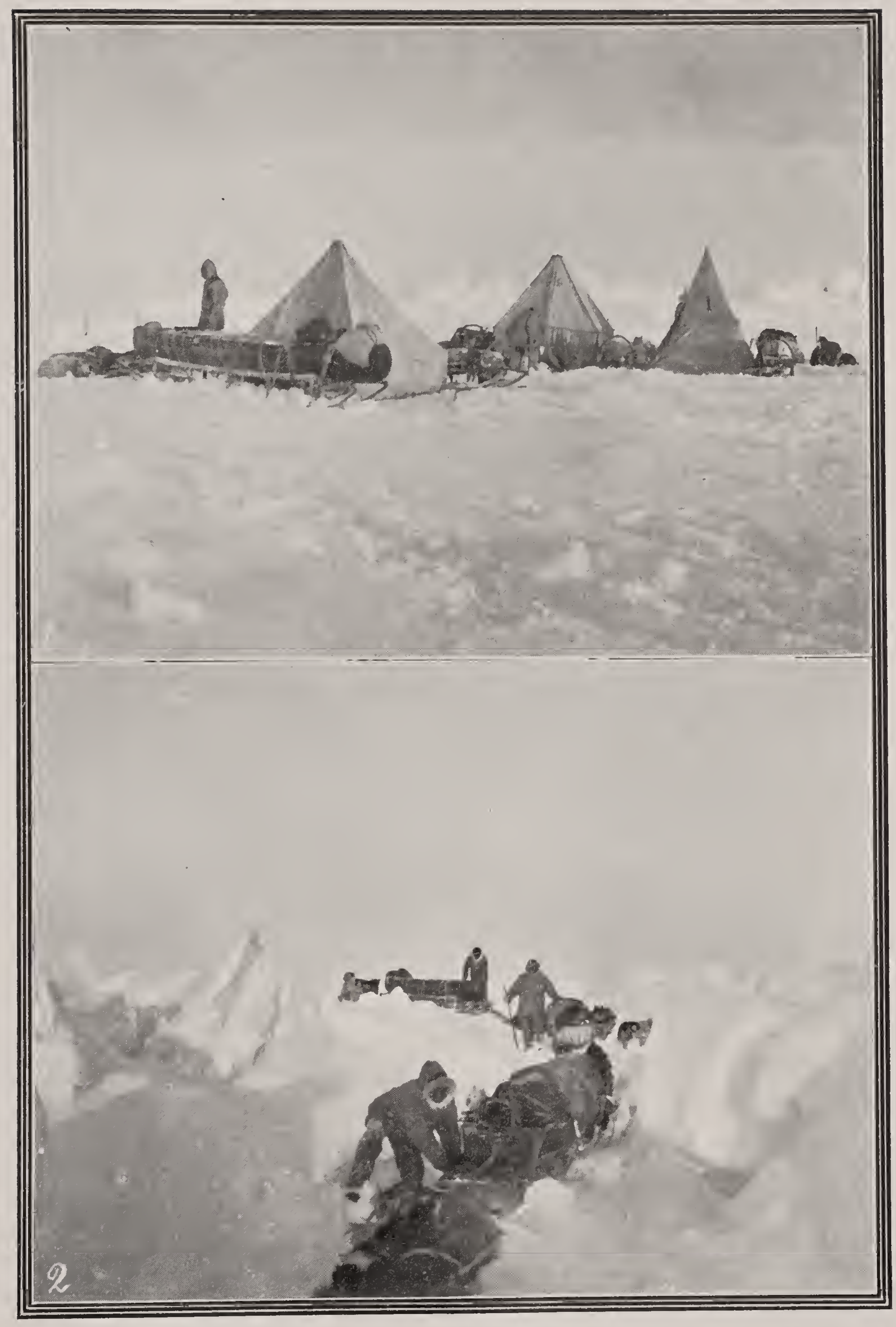
Without any seeming wish for material gain these Norsemen were the ideal explorers. Theirs were the spirit of adventure and colonization, without regard to what it would bring them as compensation for their hardships or losses.

With the disappearance of the Vikings, the Polar Seas were left untouched by the ships of men until the sixteenth century. Then came the invasion by the seamen of England, Holland, Denmark, Spain and France. Possessed by a spirit of adventure and discovery, and spurred on by the hope of finding a northeast or northwest passage to the wealth of the Orient, these hardy sailors of Europe penetrated far into the ice north of Europe and America. William Barentz of Holland reached the northwest point of Nova Zembla in July, 1594, and on another expedition in 1596 under Jacob Heemskerck in which William Barentz was navigator, Spitzbergen was discovered. Their ship, however, was lost on the shores of Nova Zembla where the party wintered, suffering many hardships. Without a ship the attempt was made on the return of summer to reach Europe in two small boats. William Barentz and a number of men died on this terrible journey. The leadership then devolved upon Heemskerck who brought the handful of survivors home.

Nova Zembla was not visited by a white man again until 1874, a lapse of two hundred and seventy-four years.

HENRY HUDSON, BOLDEST OF NAVIGATORS.

After William Barentz, came Henry Hudson, one of the boldest navigators of history. He forced his little ship, the *Hopewell,* of sixty tons to the latitude



ARCTIC EXPLORATION.—1. A Camp on the ice. 2. Crossing a pressure ridge.

of 81° and 50′ off the coast of Spitzbergen, a record that stood for nearly three hundred years, and has only been surpassed by six other expedition ships to the present day, viz:

S. S. Fram, Dr. Nansen	85° 57′ N.	1895
S. S. Roosevelt, Comm. Robt. E. Peary	82° 30′ N.	1908
H. M. S. Alert, Sir George Nares	82° 27′ N.	1875
S. S. Polaris, Charles Francis Hall	82° 11′ N.	1871
S. S. Stella Polari, Duke of the Abruzzi	82° 4′ N.	1900
S. Y. America, Anthony Fiala	82° 4′ N.	1903

A man of mystery like the country he explored, Henry Hudson came into history without a past, and when an old man, vanished in a small boat with his son and a company of sick men, the victim of a despicable crew of mutineers. In his four cruises covering many years he brought to the world more knowledge of the Polar regions than probably all the polar explorers who had preceded him.

The magnificent harbor of New York with its great river was discovered by Hudson. He attempted to round the North of Greenland from the east into Davis Strait, a feat in which he failed and which no one else has since accomplished.

THE FATE OF VITUS BERING, A DANE.

Between Henry Hudson and the explorers of the nineteenth century stands the name of Vitus Bering, a Dane. Though he started life in 1680 from the poor surroundings of a fisherman's hut, he lived to rise to the command of the largest expedition that has ever attempted to penetrate the ice barriers of the far North. For gallantry in service as a seaman, in the Czar's navy in 1707 he had been promoted to Lieutenant, and three years later to Captain-Lieutenant. He served under Peter the Great, and in 1724 received from that monarch the command of the Great Northern Expedition which had for its object the determination as to whether America and Asia were joined, and also the surveying of the northern shores of Siberia and the Arctic Ocean. It was a mammoth undertaking, and spread itself over sixteen years, costing the Russian government millions of rubles and many lives.

Bering himself was destined to pay the price of reaching the American continent with his life. His body was buried on the island which bears his name. Thirty-one of his crew also passed away after torturous suffering. With their vessel destroyed, the survivors collected the wreckage as it came ashore, and under suggestion of Waxall who was then in command, the stranded ship was pulled apart. A Cossack ship builder in the crew (Sawa Slaradoubzov) offered to build a boat, and a carpenter shop was set up on the Arctic beach. Early in May, 1742, the vessel's keel was laid, and on the 10th of August it was launched, and the forty-five survivors successfully reached the port at Petropalovski August 27th. The Russian government recognized the worth of Slaradoubzov by making him a noble.

England appeared in the ice field in 1773 in the expedition of Captain Phipps with his two vessels the *Racehorse* and the *Carcase*. Captain Phipps reached 80° 48′ latitude near the eastern shore of Spitzbergen, but was forced to return on account of the heavy ice. Young Nelson, destined later to be the hero of Trafalgar, took part in this expedition.

NAVIGATORS OF THE NINETEENTH CENTURY.

With one disaster after another as the only apparent result of the splendid efforts that had been made to open up the Arctic Sea, it is not to be wondered at that Arctic exploration lay dormant for a time. Besides, England's adventurous spirits had been engaged in the wars of that country with the United States, France, Spain and India. But in 1818 the British Admiralty, in conjunction with the Council of the Royal

Geographical Society, determined to fit out two expeditions, one under Captain John Ross and Lieutenant Edward Parry to force a northwest passage through Davis Strait, the other under Buchan and Franklin, to go by way of Greenland and Spitzbergen in search of the Pole, and to make its way home by way of Bering Strait and the Pacific Ocean. Though both expeditions returned that same year without having accomplished either the northwest passage or the Pole, they had made discoveries of land, and brought back with them that glamour of the north, which seemed to possess the navigators of the 19th century. English and Scotch whalers in their chase of the Greenland and Bering Sea whales, sailed many an uncharted Arctic Sea, and opened up miles of unknown territory; in many cases they paved the way for the explorers, their own limits of exploration being curtailed only by the bounds of the habitat of the whales they were pursuing. Captain Parry made four expeditions into the Polar Seas, the last one in 1827, an acknowledged attempt to reach the North Pole.

Parry's ship was ice beset, and he was forced to anchor her in a harbor on the shores of Spitzbergen from where he made his march north. With two boats specially constructed for the purpose, he proceeded in open water about eighty miles, and then came the trying conditions of mixed surface ice and water. Slow progress was made particularly where hummocks and pressure-ridges crossed his path. Though something like six hundred and sixty-eight statute miles were travelled, they only succeeded in making a distance of one hundred and seventy-two miles from the ship; their farthest point north on July 23 was 82° 45′ north, breaking the record for that time. In addition to being obliged to retrace their steps often in doubling back to bring up the sledge with supplies, they found that while they were traveling north the ice was drifting south.

THE MAGIC OF THE NORTH.

In 1906 the Duke of Orleans covered part of the distance Parry and his men had labored over with such heart-breaking difficulty. Standing on the bridge of his steam whaler he pushed his way through an open sea without an obstacle, a proof of the changing conditions of the Polar Ocean.

The magic of the north had long called to Captain John Ross. He had begged the British Admiralty to allow him once again to try for the northwest passage, to no avail. He succeeded at last in securing private capital to the extent of seventeen thousand pounds to which he added his own entire fortune of about three thousand pounds. A small Liverpool steamer of one hundred and fifty tons was purchased and provisioned for three years. Accompanying Captain Ross as second in command was his nephew, James Ross. They set sail in May, 1829, and were absent five years.

In April, 1830, while on a sledge trip, Commander James Ross had the good fortune to discover the North Magnetic Pole in latitude 70° 5′ 17″, longitude 96° 46′ 45″ W.

THE FORTUNES OF CAPTAIN JOHN FRANKLIN.

Coincident with the discovery of the Magnetic Pole was the work of Captain John Franklin who in three successive trips of exploration added to the map of North America fully twelve hundred square miles. In recognition of his work he was knighted. In 1845 Sir John Franklin, then in his fifty-ninth year, sailed on his last trip of exploration. With him aboard the ships *Erebus* and *Terror* were one hundred and thirty-seven officers and men, the whole party destined to disappear forever from the knowledge of men.

The search for Sir John Franklin and his companions occupied many years. His loss turned the attention of the world toward the Arctic Regions. Expedition after expedition was sent from England, but the mystery remained unsolved. In April, 1849, Lady Franklin appealed to the President of the United States, calling upon the Americans as a ''kindred people to join heart and hand in the enterprise of snatching the lost navigators from a dreary grave.''

AMERICAN EFFORT IN THE POLAR SEAS.

As a result of this plea, the country was roused into sympathy but nothing was done by legislation. It remained for Henry Grinnell, a wealthy merchant of New York, to start American effort in the Polar Seas, work which has continued to the present day, and has been rewarded with the news of the discovery of the Pole itself. To give in detail the stories of the different expeditions that began with the years 1850-51, would require several books. A large volume would be required for the story of American effort alone. In connection with the search of Sir John Franklin, and the rescue of the relics of his lost expedition, the names of Dr. Elisha Kane, Dr. Isaac I. Hayes, and Capt. Charles Francis Hall, will ever be associated. Through them thousands of square miles of territory were added to the geographical knowledge of the century. Curiously enough all these navigators had the desire to reach the Pole. In the case of Captain Hall, his avowed intention on his last expedition was to reach the coveted north point. He secured from Congress an authorization for ''an expedition to the North Pole.'' Fifty thousand dollars were appropriated, and a vessel selected and fitted out at an expense of ninety thousand more.

On August 29, 1871, Captain Hall's ship, the *Polaris,* made the high latitude of 82° 11′ N., a record which has only been surpassed to this day by three other ships. Captain Hall died after a sledge trip in the autumn, and with him perished the aim of the expedition to reach the pole, though the most northern land ever reached by civilized man at that time was attained by Sergt. F. Meyer of the U. S. Signal Corps, a member of the expedition.

In an attempt to return home, the *Polaris* was wrecked during the darkness of the Polar night, and the crew became divided, part of them going adrift on an ice floe, the remainder staying on board the leaking vessel, saving their lives by strenuous efforts at the pumps. The *Polaris* was eventually beached, and two boats were built from her timbers the following spring, in which the party made an exciting journey of two hundred miles before they were rescued by a Scotch whaler.

Stranded on their ice-cake, the other members of the *Polaris* party, nineteen souls in all, drifted through the gales and darkness of a Polar night. They suffered from hunger and exposure, but, strange to say, all, including two women and five children, lived through the five months of terror, and were rescued on April 28, by the steam sealer, *Tigress,* of New Foundland, after drifting in the Arctic ice pack thirteen hundred miles.

OTHER HEROIC NAVIGATORS.

One of the most remarkable discoveries of the nineteenth century was that of Franz Josef Land by Anton Payer. On July 13, 1872, the *Tegetthof,* the expedition ship of the Austrian Polar Expedition, left the Norwegian Coast. She was in command of Lieutenant Weyprecht with Lieutenant Payer aboard to conduct the sledge parties. On July 25 of the same year she became beset in the ice near Nova Zembla, never to be free again. She drifted through the winter at the mercy of the ice. On August 31, 1873, the party neared the shores of a hitherto unknown land which Payer named Franz Josef, in honor of his king. Another winter was passed in the ship, and the following spring Lieutenant Payer with ten men, and three dogs, and two sledges, made an exploration of the new country, reaching its most northern end to which the name of Cape Fligely was given. On again reaching their stranded ship, the entire party had to prepare for a return to civilization. It was accomplished after many hardships by the hauling of the ship's boats over the ice to the open sea. After a trip by boats to Nova Zembla they fell in with the Russian sealers who brought them home.

In 1875, Captain George S. Nares, and Commander Albert H. Markham in the British Sloop of War, *Alert,* broke all northern records for ships, and reached the high latitude of 82° 25′ N. On this expedition Commander Markham with a sledge party reached 83° 20′ N. on May 12, 1876. This record was made on the Polar ice north of Cape Joseph Henry and Grant Land. The English held this northern record until 1882 when it was surpassed by the sledge journey of Lockwood and Brainard who placed the American flag at 83° 24′ N. latitude, on the shores of North Greenland.

The years of 1879-1881 are memorable in Arctic history for the lamentable loss of Lieutenant DeLong and his men. Of three boats which left the sinking *Jeannette,* the expedition ship, only one was destined to bring its crew to safety; this was the whale boat bearing the party of Engineer Melville.

EXPEDITION OF LIEUT. A. W. GREELY.

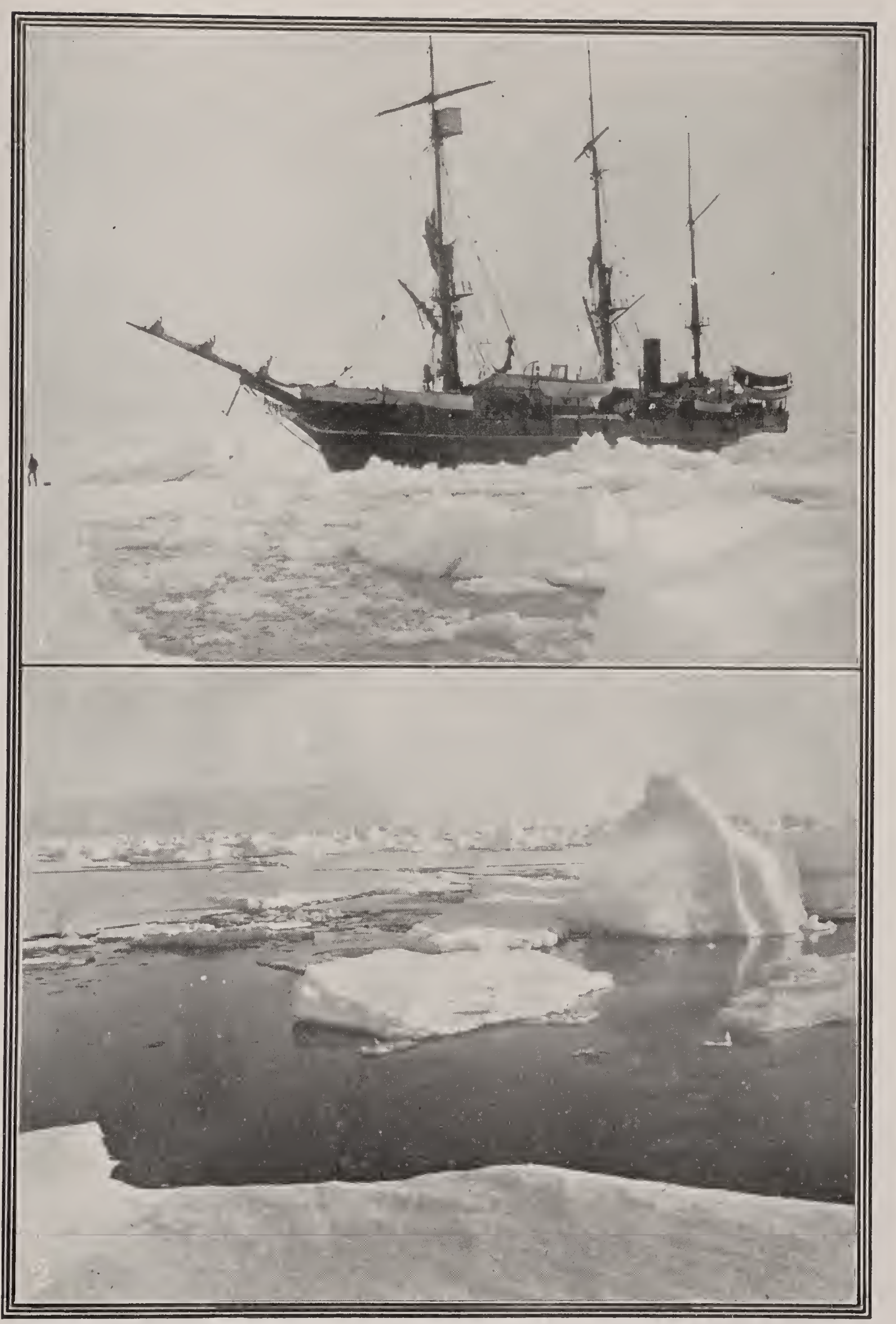
In the scheme of International Circumpolar Stations in which nine nations took part in the year 1882, the United States was represented by the Lady Franklin Bay Expedition under Lieutenant A. W. Greely of the U. S. Army. Under this splendid officer scientific work was successfuly prosecuted, and in addition sledge parties were sent out for exploration and survey. One of these under Lieutenant Lockwood and

Sergeant Brainard broke the north record of the time by reaching 83° 24′ N. latitude on May 15, 1882.

In obedience to orders from his government, Lieutenant Greely retreated with his party from his station at Fort Conger, only to suffer starvation and loss at Cape Sabine. Relief was sent when almost too late, and out of the splendid company of twenty-five, only six were left to come home.

DR. NANSEN'S ADVENTURES.

Of all the heroes of the Arctic, Dr. Nansen occupies a place unique and romantic. His was the first crossing of the Greenland ice. Landing on the desert coast of East Greenland, Nansen and his party ascended the height of the inland ice. They knew that they had to reach the west coast, or death would claim them all. The journey commenced July 29, 1888, and land was sighted on September 19th. The party suffered terribly from snow blindness; frost bites and furious gales hampered their progress. The descent was dangerous in the extreme, but they all reached the level country at the sea with joy at their wonderful success. The drift of the *Fram* across the Polar Sea, and the record-breaking march of Dr. Nansen with his companion Johannesen from their ice-bound ship, is a story which will never fail to interest. The scientific value of the drift of the *Fram,* can hardly be over-estimated. Captain Sverdrup who had accompanied Nansen over the inland ice of Greenland was navigator of the *Fram* in its three years' journey across the Polar Basin. 85° 57′ N. latitude was reached in the northward drift, making a record for polar ships that has never been surpassed. Nansen and Johannesen on April 7, 1895, made the northern record by reaching 86° 13′ 6″ N. From that point they made their long march to Franz Josef Land where they wintered in a rock-built house, like two wild men, living on polar bears and walrus, eventually reaching home through their fortunate



ARCTIC EXPLORATION.—1. A typical exploration steamer. 2. An arctic scene. The dark space in background is the reflection of water on the sky; the open water is a "lead."

meeting with the English explorer Jackson who had also wintered in the archipelago, and in whose ship these venturesome Norwegians sailed home.

July 11, 1897, Salamon August Andree, a Swede, with two companions, Messrs. Strindberg and Fraenkel, set sail from Dane Island in Spitzbergen in an immense balloon for the conquest of the pole. They are amongst the missing ones in the long list of Arctic explorers.

The Italians, under the Duke of Abruzzi, were the next to secure the prize of the most northern record on the Polar Ice. In 1899-1900, the Duke's ship, the *Stella Polari,* wintered in Teplitz Bay of the Franz Josef Archipelago, after reaching a latitude of 82° 4′. From Teplitz Bay a well organized column of men, dogs, and sledges, under Captain Cagni, attained the record of 86° 34′, a march which for distance accomplished over the polar ice, has only been exceeded by the recent reaching of the Pole by Peary.

ROBERT E. PEARY, AMERICAN EXPLORER.

Many names could be added to the list of explorers who have toiled under the adverse conditions of the frozen north, true Vikings of the Polar Seas, whose thrilling experiences have to be passed over on account of lack of space. But our story would not be complete without reference to Robert Edwin Peary who followed in the footsteps of Kane, Hayes, Hall and Greely, whose work for nearly a quarter of a century in the frozen north was completed in 1909 by his discovery of the Pole, the goal for which so many lives, ships and treasures had been exhausted in the past.

Polar exploration has been an inspiration to the age. Exploration of any sort is an education for the race of the future, a preventive measure against poverty and sickness. America owes its very existence and high place among the nations, to the fact that our fathers and mothers had the spirit of exploration and courage to break from the bonds and ruts that centuries of convention had placed them in, and with new vision, come to a new country. Because of the new pulsing vibrant life of their parents, the children of these explorers must necessarily have been different, more aggressive, and enterprising.

Polar expeditions have brought many millions of dollars as a direct result for the efforts put forth. New game fields have been discovered, and the way mapped for the fisher, hunter and whaler. The explorer's guiding charts have been the means of saving many a life, and the trips from continent to continent, across the oceans of the earth, have been rendered shorter and safer by the knowledge of terrestrial magnetism gained through voyages of exploration.

CHAPTER LXXV.

South Polar Exploration.

A FROWN THAT IS A LURE.

OUR strange old world is tipped with eternal ice-caps. The North Pole and South Pole, the Arctic and the Antarctic, frown across smiling regions at each other and at the inhabitants of happier climes. But the frown, forbidding as it is, has for centuries been a constant lure to those who love adventure, and to men desirous of learning all there is to learn about our wonderful planet. That sufferings awaited explorers in these terribly desolate and frozen regions, could not deter them from the undertaking; that death itself was often a companion on the voyage was not taken into account when weighed in the balance with the fascination of discovery. The cold, cruel, but glittering flash of the everlasting ice, served but to lead men on; and the pages of history contain no more heroic names than many of those who have penetrated these regions, some to die there, and others to return and add to the store of human knowledge.

ICE-CAPS, ICEBERGS, AND HOWLING WINDS.

The South Pole is now known to be the center of a great continent or a group of immense islands, which, on some accounts, makes it easier of approach than was the case at the North Pole; on the other hand, there are altitudes not found in the north, and bleak exposed plateaus, that are the homes of terrible storms. Indeed, the Antarctic winds blow with a fury and malignant force found nowhere else in the world. The mountains are ice-capped; two of them are volcanoes; Mt. Erebus, over thirteen thousand feet high, and Mt. Terror, extinct, nearly eleven thousand feet high.

Enormous icebergs, flat-topped, with perpendicular walls and often measuring many miles in extent are found everywhere throughout the Antarctic Ocean; they seem to have been broken off from the great ice-cap covering Antarctic lands. Bruce tells of some that were ninety miles in length and two thousand feet thick. The thickness of the ice toward the pole is estimated to be, in places, at least ten miles.

SPASMODIC JOURNEYS TO THE SOUTHLAND.

Active exploration of the Antarctic is of comparatively recent date. Captain Cook was the first to cross the Antarctic circle, which he did in 1773; he dispelled the illusion that New Zealand was a part of the southern continent. The circle seems not to have been approached again until 1819 when a Russian, Captain von Bellingshausen, was the first to discover the Antarctic mainland, which he called Alexander Land.

Several other daring explorers ventured into the south seas during the next twenty years, all of them giving their names to the portions of land they sighted, among them Capt. Charles Wilkes, of the United States Navy.

In 1840 the best equipped expedition, up to that time, was fitted out under Captain James Ross who discovered a tract of ice-burdened land which he called Victoria Land; he followed it for nearly six hundred miles and then penetrated for two hundred and fifty miles further, the ice barrier into which it merged. He discovered several mountain ranges also, and the south magnetic pole.

Then enthusiasm for prodding into the secrets of this forbidding, inhospitable coast appears to have waned, but just at the close of the century it flamed into new life again, though whaling vessels were constantly going into the Antarctic zone. The first winter passed by man within the Antarctic circle was that of 1898-9; the expedition was under the command of Captain de Gerlach and was under Belgian auspices. About the same time a German zoologist, Chun, and an English party under Mr. C. E. Borchgrevink, the latter wintering, went into Antarctica.

A NEW EPIDEMIC.

In 1902-6 a new epidemic of Antarctic exploration broke out and five nations carried their flags beyond the Horn in an effort to reach ''Farthest South.'' There were two British expeditions, one that discovered new regions which were named Edward VII Land, and another, under Captain Robert F. Scott, accompanied by Lieutenant Shackleton, that reached 82° 17′ south latitude. They proved Victoria Land to be a great continental plateau, nine thousand feet above sea level. A German expedition, under Drygalski, discovered new territory which was named Kaiser Wilhelm II Land. A Scotchman—you would know he was Scotch from his name, which was Bruce—made important discoveries; and a Frenchman, Charcot, headed two expeditions that yielded valuable results.

LIEUTENANT SHACKLETON'S "FARTHEST SOUTH."

Then came Lieut. Ernest H. Shackleton, with his splendid equipment—a man whose name will be forever associated with South Polar history. He commanded the British Antarctic expedition of 1907-9, making four land journeys from his base of supplies. On one of these journeys he ascended Mt. Erebus, the active volcano, finding its great crater to be nine hundred feet deep and half a mile high; and that there was intense internal heat underlying even this frozen land was shown by the reflection of the molten lava on the clouds—a weird and wonderful sight!

Another journey undertaken in the southern summer of 1908-9—our winter—was the most notable sledging exploit on record. Lieutenant Shackleton penetrated far into the interior of the continent, ascending the mighty ice-cap by way of a glacier one hundred and thirty miles long whose top was reached at an altitude of over ten thousand feet. Here the wind sometimes blew at from eighty to ninety miles an hour with temperatures of minus sixty degrees—conditions which the party could meet only by lying cosily ensconced in their sleeping bags till the blow was over. Food was failing, but still the party pushed on until January 9, 1909, when they were at south latitude 88° 23′, one hundred and eleven miles from the south pole; from this point they were obliged to turn back, but it marked "Farthest South."

On his return to England, Lieutenant Shackleton was knighted, received the Polar Medal—two bars—and the highest honors that the scientific societies of Europe could bestow.

A GLORIOUS RACE OF HEROES.

At present writing, 1911, there are at least three great expeditions in a race for the prize of actually reaching the south pole. An English party is under command of Captain Scott; Lieutenant Filchner is lead-

OCT 26 1911

ing a German expedition; and Captain W. S. Bruce heads a Scottish exploring party. In order not to interfere with one another, arrangements have been made to enter the field at different points and work in separate zones. Whether the south pole is discovered in this campaign or not, Sir Ernest Shackleton is planning to make another journey in 1912, in order to gain new scientific data regarding the mysterious continent.

It is an exciting and glorious race, and one whose outcome is eagerly awaited by the whole civilized world.

One copy del. to Cat. Div.

OCT 26

LIBRARY OF CONGRESS
0 019 892 059 9